Fractures of the proximal femur in children and adolescents

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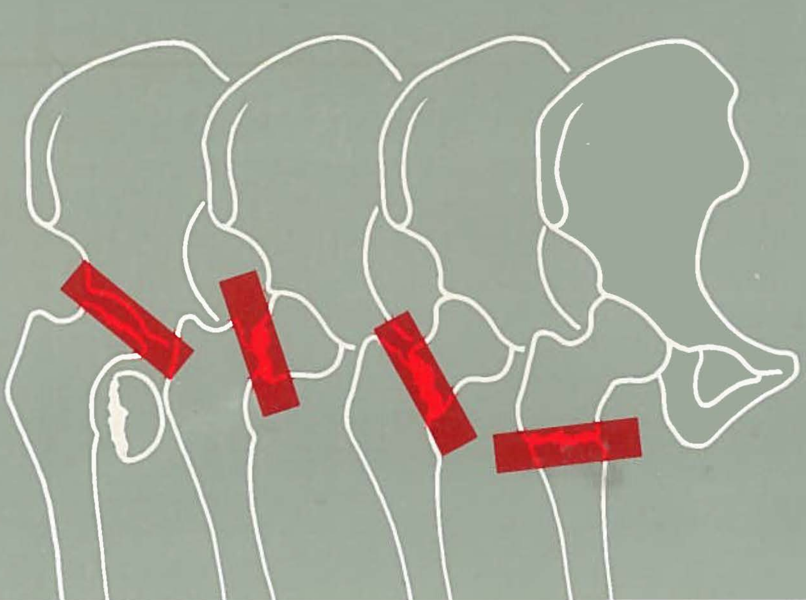
H.J. HOEKSTRA

FRACTURES OF THE PROXIMAL FEMUR IN CHILDREN AND ADOLESCENTS



FRACTURES OF THE PROXIMAL FEMUR IN CHILDREN AND ADOLESCENTS

STELLINGEN

I.

De indicatie tot conservatieve of operatieve behandeling van proximale femurfracturen bij kinderen en adolescenten wordt bepaald door het type fractuur, de leeftijd van de patient en de eventueel aanwezige, begeleidende letsels.

II.

De kans op het optreden van een avasculaire necrose van het caput en/of collum femoris na een proximale femurfractuur, bij het kind of de adolescent, wordt voornamelijk bepaald door de leeftijd van de patient, het type fractuur, de mate van dislocatie van de fractuur en de wijze van behandeling.

III.

Bij patienten met homolateraal een collum femoris fractuur en een femurschachtfractuur dienen beide fracturen operatief behandeld te worden.

IV.

Kinderen en adolescenten die vanwege een maligniteit in het onderste gedeelte van de buik bestraald worden, al of niet in combinatie met cytostatica, hebben een verhoogde kans op het optreden van een epiphysiolysis coxae.

V.

Pertrochantere femurfracturen bij kinderen en bij adolescenten dienen bij voorkeur conservatief behandeld te worden.

VI.

Het per endoscoop biopteren van een gladde oesophagusimpressie, met normaal uitziende mucosa, is niet juist.

VII.

De behandeling van een synchrone bilaterale primaire kiemceltumor van de testis is in principe gelijk aan die van een enkelvoudige primaire kiemceltumor van de testis en wordt bepaald door histologie en metastasering.

VIII.

Door de Ernst Gradering van Ongevals-Slachtoffers (EGOS) toe te passen bij de Meervoudig Ernstig Gewonde patient (MEG-patient), wordt een objectieveerbare, reproduceerbare „maat" verkregen over de ernst van de letsels.

IX.

Van het college Medische Statistiek dienen methodologie - met name het opstellen van een onderzoek - en analyseplan, het verzamelen en vastleggen van patientengegevens en het bewerken van onderzoekgegevens met behulp van statistische programmatuur - een wezenlijk onderdeel te vormen.

X.

Voor een adequate statistische bewerking van patientengegevens is het vastleggen van deze gegevens op basis van vooraf geformuleerde vraagstellingen en een analyseplan een noodzakelijke voorwaarde.

XI.

Er worden in de regel in ziekenhuizen niet alleen teveel röntgenfoto's aangevraagd, er worden er ook teveel beoordeeld.

XII.

De integraal-helm biedt bij een ongeval een betere bescherming van het aangezicht dan de jet-helm.

XIII.

In Nederland leidt de toename van poliklinische gezondheidszorg niet tot het afnemen van de omvang van de klinische gezondheidszorg.

XIV.

Versterking van de eerstelijns gezondheidszorg leidt niet tot een afname van de vraag naar diensten in de tweede lijn.

XV.

Het kunstgras van de meeste hockeyvelden is een geurloos grastapijt.

Stellingen
behorende bij het proefschrift van
H. J. Hoekstra

Fractures of the Proximal Femur in Children and Adolescents

Groningen, 17 november 1982

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to: Josette
Hessel
Carlijn
Joris

CONTENTS

Chapter I		INTRODUCTION	1
	I.1	Introduction	1
	I.2	Aim of the study	2
Chapter II		ANATOMY AND DEVELOPMENT OF THE ARTERIAL VASCULARIZATION OF THE PROXIMAL FEMUR	4
	II.1	Introduction	4
	II.2	The proximal femur	4
	II.3	The joint socket	5
	II.4	The hip-joint	6
	II.5	The joint capsule	6
	II.6	The ligaments	6
	II.7	The arterial vascularization of the proximal femur	7
	II.7.1	The extracapsular and the subsynovial intra-articular vascular ring	8
	II.7.2	The arterial vascularization via the ligamentum capitis femoris	10
	II.7.3	The intra-osseous vessels of the proximal femur	10
	II.8	The development of the arterial vascularization of the proximal femur	11
	II.8.1	Stage I. Vascularization at birth	12
	II.8.2	Stage II. Vascularization between 4 months and 3 years	12
	II.8.3	Stage III. Vascularization between 4 and 7 years	12
	II.8.4	Stage IV. Vascularization during pre-adolescence, from 7 to 13 years	13
	II.8.5	Stage V. Vascularization during adolescence	13
	II.8.6	Summary	13

Chapter III		FRACTURES OF THE PROXIMAL FEMUR	15
	III.1	Introduction	15
	III.2	Classification of proximal femoral fractures	15
	III.2.1	Type I. Traumatic separation of the upper femoral epiphysis	16
	III.2.2	Fractures of the femoral neck	17
	III.2.2.1	Type II. Transcervical fracture	18
	III.2.2.2	Type III. Basal or cervico-trochanteric fracture	18
	III.2.3	Type IV. Pertrochanteric fracture	18
	III.3	Aetiology	18
	III.4	Clinical signs	19
	III.5	Radiographic examination	19
	III.6	Summary	19
Chapter IV		COMPLICATIONS OF FRACTURE HEALING	21
	IV.1	Introduction	21
	IV.2	Avascular necrosis	21
	IV.2.1	Introduction	21
	IV.2.2	Incidence	22
	IV.2.3	Aetiology	23
	IV.2.4	Types of avascular necrosis in children and adolescents	24
	IV.2.5	Clinical symptoms	26
	IV.3	Delayed union and non-union	27
	IV.4	Posttraumatic coxa vara	28
	IV.5	Premature epiphyseal fusion	29
	IV.6	Difference in leg length	31
	IV.7	Arthritis	31
	IV.8	Summary	32
Chapter V		PATIENTS AND METHOD OF INVESTIGATION	33
	V.1	Patients	33
	V.2	Method of investigation	34
Chapter VI		CLINICAL DATA	35
	VI.1	Introduction	35
	VI.2	Incidence	35

	VI.3	Age and sex distribution	37
	VI.4	Cause and site of the accident	39
	VI.4.1	Cause of the accident	39
	VI.4.2	Site of the accident	41
	VI.5	Fracture types	41
	VI.5.1	Age and sex distribution	41
	VI.5.2	Left-right distribution	42
	VI.5.3	Displacement	43
	VI.6	Pre-existent diseases	45
	VI.7	Concomitant lesions	46
	VI.8	Summary	48
Chapter	VII	TREATMENT	49
	VII.1	Introduction	49
	VII.2	Review of the historical development of various methods of treatment	49
	VII.3	Indications for conservative or operative treatment	53
	VII.4	Conservative treatment	54
	VII.4.1	The hip spica	54
	VII.4.2	Traction	54
	VII.4.3	Combination of hip spica and traction . .	55
	VII.5	Operative treatment	55
	VII.5.1	Cancellous bone screws	55
	VII.5.2	Pins	56
	VII.5.3	Kirschner wires	56
	VII.6	The operation	56
	VII.7	Postoperative treatment	57
	VII.8	Treatment of complications of fracture healing	57
	VII.8.1	Avascular necrosis	57
	VII.8.2	Non-union	58
	VII.8.3	Posttraumatic coxa vara	59
	VII.8.4	Premature epiphyseal fusion	59
	VII.8.5	Difference in leg length	59
	VII.8.6	Arthritis	60
	VII.9	A survey of the methods of treatment used in the Groningen patients	60
	VII.9.1	Conservative treatment	62

	VII.9.2	Operative treatment	62
	VII.9.3	Method of reduction, time of reduction, and reduction achieved	63
	VII.9.4	Systemic and local complications during treatment	64
	VII.9.5	Duration of hospitalization	64
	VII.10	Discussion	64
Chapter	VIII	METHODOLOGY OF FOLLOW-UP	66
	VIII.1	Introduction	66
	VIII.2	Method of locating patients	66
	VIII.3	Follow-up methods	66
	VIII.3.1	History	67
	VIII.3.2	Physical examination	67
	VIII.3.3	Radiographic examination	67
	VIII.3.3.1	Anteroposterior radiograph of the pelvis	67
	VIII.3.3.2	Anteroposterior radiograph of the pelvis in the Lauenstein projection	69
	VIII.3.3.3	Anteroposterior radiograph of both lower extremities	69
Chapter	IX	THE RESULTS OF THE STUDY	72
	IX.1	Introduction	72
	IX.2	The patients examined	72
	IX.3	Functional results	73
	IX.3.1	Mobility of the hip-joint	73
	IX.3.2	Gait	77
	IX.3.3	Complaints of pain in the hip	78
	IX.3.4	Discussion	78
	IX.4	Anatomical results	79
	IX.4.1	Radiographic leg length measurement	79
	IX.4.2	Changes in the position of the proximal femur	80
	IX.4.3	Pelvic asymmetry, Trendelenburg's sign and the circumference of the femoral quadriceps muscle	82
	IX.4.4	Discussion	84
	IX.5	Radiographic findings	85
	IX.5.1	Radiographic features of the proximal femur	85
	IX.5.2	Avascular necrosis of the proximal femur	88

IX.5.3	Premature epiphyseal fusion	91
IX.5.4	Non-union	92
IX.5.5	Posttraumatic osteoarthritis of the hip-joint	92
IX.5.6	Discussion	94
IX.6	Short-term and long-term social consequences	95
IX.6.1	The choice of education and occupation . .	95
IX.6.2	Medical examination for military service and subsequent occupation	96
IX.6.3	Day-to-day activities	97
IX.6.4	Subsequent operations on the proximal femur	97
IX.6.5	Discussion	97
IX.7	The results of treatment	98

SUMMARY AND CONCLUSIONS 102

SAMENVATTING EN CONCLUSIES 108

REFERENCES 115

CHAPTER I

INTRODUCTION

I.1 Introduction

Proximal femoral fractures in children and adolescents are rare. In 1839 Dupuytren, discussing "des fractures du col du fémur, leur causes et leur traitement" in the "leçons orales de clinique chirurgicale", noted that he himself had never diagnosed a fracture of the proximal femur in a child. The first reports on a proximal femoral fracture in a child were published by Barber (1871), Cromwell (1885) and Hamilton Russell (1889). In 1918 Sir John Bland-Sutton described two proximal femoral fractures in children in the "SPOLIA OPIMA". One was an anatomical specimen dated 1883, from the Middlesex Hospital, while the other was a fracture in a 12-year-old boy. Bland-Sutton concluded: "Senile femurs with broken necks abound in pathological museums, but I doubt if five examples obtained from boys or girls exist in all the museums of the United Kingdom". The publications of Royal Whitman on fractures of the proximal femur in children (1891, 1893, 1897, 1900 and 1909) are of great historical value. Most diagnoses were based on clinical findings. After 1897 it became possible to confirm the clinical diagnosis radiologically, and a distinction could be made between proximal femoral fracture, slipped capital femoral epiphysis and congenital coxa vara. Whitman's conclusion on the basis of clinical findings that proximal femoral fractures were more uncommon in children than slipped capital femoral epiphysis, was no longer tenable (Sprengel, 1899; Hoffa, 1903; Schwartz, 1913; Greig, 1919).

Children and adolescents differ from adults and aged persons in that the incidence of proximal femoral fractures is very low. In 1961 McDougall wrote: "Fracture of the neck of the femur in childhood is uncommon, and few surgeons have the opportunity of treating more than one or two in the course of their careers".

Disturbances in fracture healing are generally rare in children and adolescents, but this does not apply to proximal femoral fractures. Blount (1955) in fact wrote: "True fractures at the proximal end of the femur are so rare that no one has a great experience with them. They are usually indifferently treated with bad results".
In the aged, fractures readily occur in the osteoporotic bone of the proximal femur; in many cases only a minor trauma suffices to produce a fracture. Sometimes it is not even clear whether the fall caused the fracture or vice versa (Garden, 1961). Considerable forces, however, are required to cause a fracture of the very strong bone of the proximal femur in a child or adolescent. Such forces can act either directly, on the greater trochanter, or indirectly, axially, on a preferably rotated femur. Accidents which involve such forces rarely occur in children and adolescents.
The literature comprises only a few series of more than 50 children and adolescents with proximal femoral fractures (Lam, 1971; Gupta and Chaturvedi, 1973; Talwalker, 1974; Canale and Bourland, 1977; Ratliff, 1978; Pförringer and Rosemeyer, 1980; Pathak et al., 1980). The patients with proximal femoral fractures in these series were treated in various ways, with many disturbances in fracture healing.
There is apparently no consensus about the treatment of choice of fractures of the proximal femur in children and adolescents. All authors, however, agree that proximal femoral fractures are rare in children and adolescents, and often give rise to disturbances in fracture healing.

I.2 Aim of the study

The aim of this explorative retrospective study is to gain insight into the aetiology and clinical features of proximal femoral fractures in children and adolescents, and the relation to the treatment given and its short-term or long-term results.
The overall aim of this study can be specified in the following problem statements:

- What are the correlations between the relevant clinical data on the proximal femoral fracture, and which relations to the circumstances of the accident are demonstrable.
  - What is the incidence of proximal femoral fractures in children and adolescents as compared with that in adults.
  - What are the circumstances of the accident.
  - Is there a correlation between the various clinical data.

- Which factors influence the healing of these fractures.
- What is the short-term or long-term prognosis of fractures of the proximal femur in children and adolescents, particularly in terms of:
  - Disturbances in the growth and development of the proximal femur.
  - Disturbances in the function of the affected leg.

CHAPTER II

ANATOMY AND DEVELOPMENT OF THE ARTERIAL VASCULARIZATION OF THE PROXIMAL FEMUR

II.1 Introduction

This chapter presents a survey of the anatomy of the hip (Lang and Wachsmuth, 1972) and the development of the arterial vascularization of the proximal femur in children and adolescents.

II.2 The proximal femur

The proximal femur consist of the femoral head, the femoral neck and the trochanteric complex comprising the greater and the lesser trochanter.
The femoral head is covered with cartilage, except at the centre of the hemispherical cartilage surface, where a depression is found: the fovea capitis femoris, which is the site of attachment of the ligamentum capitis femoris. The femoral neck is oval-shaped in cross-section, with the flattenings on the ventral and the dorsal side. The axis of the femoral neck and the axis of the femur form the Centrum-Collum-Diaphysis angle: the CCD-angle or angle of inclination of the femur, which opens medio-caudadly. This CCD-angle varies with age, sex, and the size and width of the pelvis. In neonates the CCD-angle ranges from 117° to 143°, averaging 137°. The angle increases during the first three years of life, and decreases again after the third year. In adults the CCD-angle ranges from 120° to 140°, dependent on age and sex (Mercer and Duthie, 1964). With advancing age the CCD-angle diminishes, and in females it is smaller than in males. With advancing age the CCD-angle averages 126°.
The plane through the axes of the femoral neck and the femoral shaft forms an angle with the plane through the axis of the femoral condyles parallel with the axis of the femur: the so-called anteversion angle (AV-angle),

which opens medio-ventradly. In the course of femoral growth and development the AV-angle diminishes, and in adults it averages 12°, with a very wide range. The average male AV-angle is slightly smaller than the average female AV-angle, and that of the right femur is slightly smaller than that of the left. No correlation has been established between the age and the size of the AV-angle and CCD-angle (Brouwer, 1980).
The proximal femur has two large bony prominences: craniolaterally the greater trochanter and mediodorsally the lesser trochanter. On the ventral side the two trochanters are linked by a slightly arched line: the intertrochanteric line. A bony ridge on the posterior side is the intertrochanteric crest. The intertrochanteric line and crest form the transition between femoral neck and femoral shaft.
At birth, the entire proximal femur consists of cartilage. The ossification centre of the femoral head appears at the latest between the 11th and the 12th month of life in males, and between the 7th and the 8th month in females. The greater and the lesser trochanter each have their own ossification centre; that of the greater trochanter appears between the 2nd and the 5th year of life, and that of the lesser trochanter by about the 11th year. The epiphysis of the femoral head fuses with the diaphysis by about the 19th or 20th year of life, and sometimes even later. Both the appearance of the ossification centres and the closure of the epiphyseal plates occur earlier in females than in males.

II.3 The joint socket

Except for the acetabular fossa, the acetabulum is covered with cartilage: the facies lunata acetabuli. The acetabular fossa contains adipose tissue, in addition to other structures. This adipose tissue prevents incarceration of the ligamentum capitis femoris between the ball and the socket of the joint. The facies lunata acetabuli is continuous with the cartilage on the inside of the acetabular lip.
The acetabulum is part of the hip-bone and, together with fibrous and cartilaginous structures, constitutes the joint socket. The bony edge of the acetabulum - the acetabular margin - is interrupted on the inferior side by the incisura acetabuli. The incisura acetabuli is bridged by the transverse acetabular ligament. The acetabular lip, which attaches to the acetabular margin and the transverse acetabular ligament, with the acetabulum encompasses almost two-thirds of the femoral head.

II.4 The hip-joint

The hip-joint or articulatio coxae, i.e. the joint between the mediadly pointing proximal femur and the hip-bone, is a ball-and-socket joint in which the socket encompasses more than one-half of the ball. This particular type of joint is known as nut joint or enarthrosis.
In the hip-joint, the movements about three perpendicularly arranged axes are designated as: anteflexion, retroflexion, abduction, adduction, external rotation and internal rotation.

II.5 The joint capsule

The fibrous capsule arises from the acetabular margin immediately outside the acetabular lip and the transverse acetabular ligament. It attaches ventrally and dorsally at equal distances from the femoral head. On the ventral side the fibrous capsule is attached to the intertrochanteric line, while on the dorsal side the attachment is medial to and parallel with the intertrochanteric crest; consequently the distal one-third of the femoral neck is dorsally not covered by the joint capsule.
The synovial membrane covers the inside of the fibrous capsule, envelops the ligamentum capitis femoris and lines intra-articular bone surfaces. The synovial membrane attaches to the edges of the joint surfaces and reverses at the site of insertion of the fibrous capsule on the femoral neck.

II.6 The ligaments

The fibrous capsule consists of bundles of fibres extending mediolateradly or spiralling around the synovial membrane except on the postero-inferior side. The fibres arise from the outer edge of the acetabulum and the inferior anterior iliac spine. Three strong, spiralling bundles of fibres are distinguishable in the fibrous capsule: the iliofemoral, the pubofemoral and the ischiofemoral ligament. Between these three spiral fibre bundles and the synovial membrane, a fourth bundle of fibres extends: the orbicular zone of the hip-joint.

The iliofemoral ligament consists of two parts which, fanning out from the inferior anterior iliac spine, extend along the ventral side to the greater trochanter and the intertrochanteric line. The iliofemoral ligament is the strongest ligament, which inhibits abduction and retroflexion, adduction and external rotation.

The pubofemoral ligament extends from the inferior side of the pubic bone along the ventrocaudal aspect of the hip-joint, parallel with the axis of the femoral neck, to the intertrochanteric line. This ligament inhibits abduction and retroflexion.
The ischiofemoral ligament extends from the body of the ischium on the dorsocaudal side of the hip-joint and inserts on the anterior aspect of the greater trochanter. This ligament inhibits retroflexion and internal rotation.
The orbicular zone comprises fibres between the synovial membrane and the three abovementioned ligaments. These fibres are particularly well-developed in the lateral part of the capsule. They can be described as a loop, suspended from the inferior anterior iliac spine. The orbicular zone inhibits adduction.
The ligamentum capitis femoris is a fibrous band which extends from the edge of the incisura acetabuli, the acetabular fossa and the transverse acetabular ligament to the fovea capitis femoris. This ligament may be very thin or even entirely absent. The blood vessels which may extend in this ligament, contribute to the vascularization of the femoral head.

II.7 The arterial vascularization of the proximal femur

The femoral head and most of the femoral neck are localized within the capsule and therefore cannot be directly supplied with blood from adjacent soft tissues. The vascularization of the femoral head and neck varies with age. During the growth phase there are marked differences in the vascularization of the proximal femur.
The adult proximal femur is vascularized by branches of the medial and the lateral circumflex femoral artery and the obturator artery via the ligamentum capitis femoris (Howe et al., 1950). The medial and lateral circumflex femoral arteries form the extracapsular vascular ring. Branches of this extracapsular vascular ring form the subsynovial intra-articular vascular ring (Chung, 1976).
In their studies of the vascularization of the proximal femur, Trueta and Harrison (1953), Crock (1965, 1967) and Chung (1976) presented excellent detailed historical reviews of the development of the vascularization of the proximal femur. In this study the vascularization of the femur in adults will be discussed first; this will be followed by a discussion of the development of the vascularization of the proximal femur in children and adolescents, as described by Trueta (1957).

II.7.1 *The extracapsular and the subsynovial intra-articular vascular ring*

The medial and lateral circumflex femoral arteries can arise from the femoral artery, the deep femoral artery or the superficial femoral artery. The medial circumflex femoral artery as a rule arises from the femoral artery, while the lateral circumflex femoral artery arises from the deep femoral artery (Chung 1976). The medial circumflex femoral artery extends between the iliopsoas muscle and the pectineal muscle along the dorsal aspect of the femoral neck, parallel with the intertrochanteric crest, to the intertrochanteric fossa. The lateral circumflex femoral artery extends lateradly, ventral to the iliopsoas muscle, passing beneath the femoral rectus muscle along the intertrochanteric line to the greater trochanter.

At the greater trochanter the medial circumflex femoral artery anastomoses with the lateral circumflex femoral artery. Together, they form the extracapsular vascular ring (Crock, 1965). This vascular ring is localized around the base of the femoral neck at the level of the attachment of the fibrous capsule to the femoral neck. Most of this vascular ring - the medial, dorsal and lateral parts - is formed by the medial circumflex femoral artery. The lateral circumflex femoral artery forms only the ventral part of the extracapsular vascular ring (fig. 1).

The medial circumflex femoral artery produces three rami. The first, distributed early in its course along the intertrochanteric crest, is the ramus nutritius capitis et colli inferioris; this ramus passes through the fibrous capsule of the hip-joint, takes a subsynovial course and distributes a few epiphyseal, but mainly metaphyseal rami. The other rami - the ramus nutritius colli posterioris and the ramus nutritius capitis et colli superioris - likewise pass through the fibrous capsule, extend subsynovially and distribute metaphyseal and epiphyseal rami. The lateral circumflex femoral artery produces one large ramus: the ramus nutritius colli anterioris, which passes through the fibrous capsule and takes a subsynovial course along the anterior aspect of the femoral neck (fig. 2).

These four groups of subsynovial intra-articular arteries (ventral, medial, dorsal and lateral) depart from the extracapsular vascular ring at fixed sites and, along the surface of the femoral neck, extend to the cartilage which separates the head from the neck of the femur. At the level of the transition from femoral neck to femoral head, they form the subsynovial intra-articular vascular ring (Chung, 1976).

Both the extracapsular and the subsynovial intra-articular vascular ring may be incomplete.

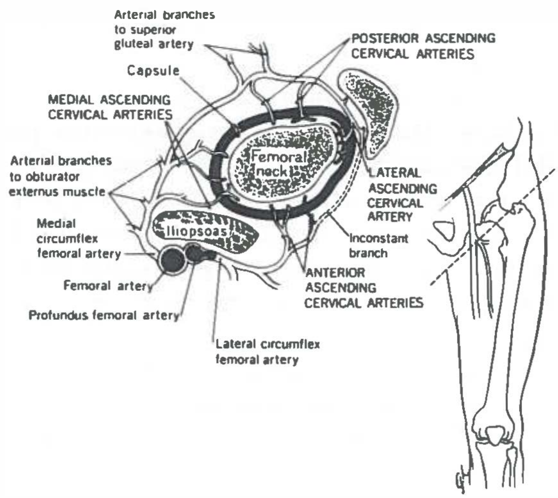
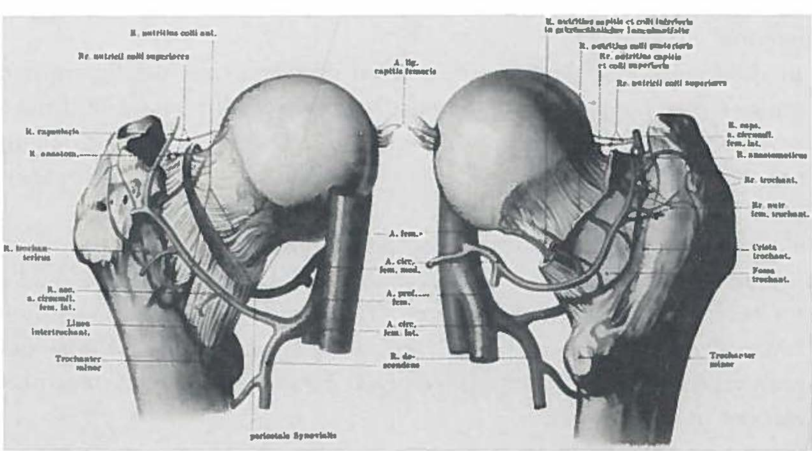


Fig. 1. Proximal left femur cross section at the neck base shows the extracapsular ring and arteries traversing the capsule. Broken lines indicate inconstant connections between anterior and lateral ascending cervical arteries. Note how the lateral ascending cervical artery branches after traversing the capsule. In young children this artery can be compressed in the very narrow space between the femoral neck and greater trochanter as the artery passes through the capsule (Reproduced from Stanley M. K. Chung: Hip disorders in infants and children. Philapdelphia: Lea and Febiger, 1981).



Ventral Dorsal

Fig. 2. The arterial vascularization of the proximal femur. (Reproduced from Lang J. and Wachsmuth W., hrsg. Lanz und Wachsmuth: Praktische Anatomie Bd 1/4. Bein und Statik. 2. Aufl. Berlin: Springer, 1972).

II.7.2 *The arterial vascularization via the ligamentum capitis femoris*

The obturator artery arises from the internal iliac artery and exits from the true pelvis via the obturator foramen, whereupon it divides into an anterior and a posterior ramus. The acetabular ramus arises from the posterior ramus at the level of the incisura acetabuli. From this ramus arises the artery which extends in the ligamentum capitis femoris. However, this artery may also arise from the epigastric artery, the external iliac artery, the femoral artery or even the medial circumflex femoral artery. Very often there are extensive anastomoses between the obturator artery and the medial circumflex femoral artery.

The artery which extends in the ligamentum capitis femoris is sometimes called foveolar artery or arteria ligamenti capitis foveolaris. Several arteries may extend in the ligamentum capitis femoris; they are sometimes described as the medial epiphyseal vessels (Trueta, 1957).

The presence or absence of arterial vascularization via the ligamentum capitis femoris, and its contribution to the circulation of the femoral head, are a controversial subject. According to Kolodny (1925), Wolcott (1943), Sevitt and Thompson (1965) and Wertheimer (1971), the contribution of arterial vascularization via the ligamentum capitis femoris to the circulation of the femoral head is minimal in adults. Phemister (1934), Tucker (1949), Trueta (1957) and Catto (1965), however, attach great importance to the arterial vascularization of the femoral head via the ligamentum capitis femoris.

In children and adolescents the arterial circulation via the ligamentum capitis femoris contributes to the vascularization of the femoral head and to its growth and development (Kolodny, 1925; Trueta, 1957). The findings reported by Wolcott (1943), Tucker (1949) and Howe et al. (1950) are at odds with this view.

The contribution to the arterial vascularization of the femoral head via the ligamentum capitis femoris is small in adults. Only one-fifth to one-third of the femoral head is thus vascularized (Trueta, 1957; Sevitt and Thompson, 1965). The specific contribution to the arterial vascularization of the femoral head via the ligamentum capitis femoris is discussed in detail in subsequent sections of this chapter.

II.7.3 *The intra-osseous vessels of the proximal femur*

The entire proximal femur consists of cartilage during the first two years of life. Numerous blood vessels extend from the diaphysis to the developing epiphysis. About the second year of life an ossification centre appears in the epiphysis, and enchondral ossification commences. At this time the epiphyseal plate constitutes a barrier between the intra-osseous vessels in the metaphysis and the epiphysis. The intra-osseous vessels in the diaphysis and the metaphysis, however, constitute an entity. The diaphysis is vascularized via the nutrient arteries from the perforating arteries of the deep femoral artery, whereas the metaphysis is vascularized via blood vessels arising from the intra-articular vascular ring.

II.8 The development of the arterial vascularization of the proximal femur

The development of the arterial vascularization of the proximal femur is discussed with reference to the studies of Trueta (1957) (fig. 3).

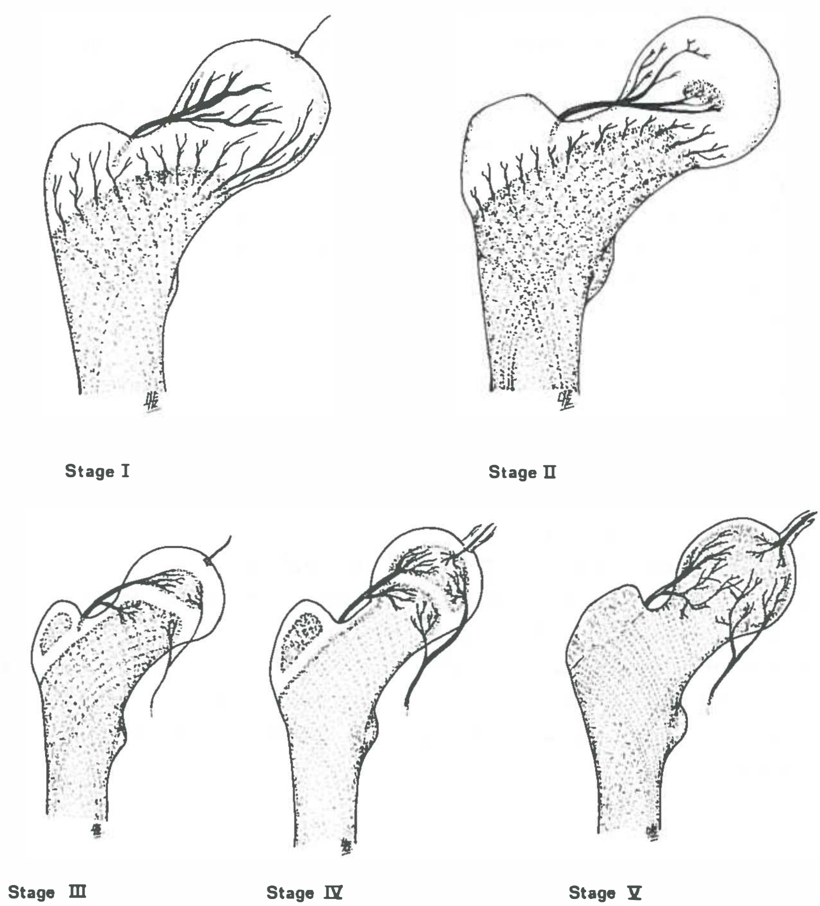


Fig. 3. The development of the arterial vascularization of the proximal femur.

II.8.1 *Stage I. Vascularization at birth*

The process of ossification begins during the foetal period in the femoral shaft, and at the time of birth has reached the proximal femur. From the edge of the ossification centre, 10-15 small vessels ascend in the cartilaginous proximal femur. They arise mainly from the medial aspect of the metaphysis and extend to a certain distance from the edge of the cartilaginous proximal femur. Another group of vessels enters the proximal femur laterally from the incisure of the greater trochanter and takes a horizontal course to the centre of the developing femoral head. The two vascular systems decussate almost perpendicularly, therefore, to form the rami colli et capitis inferiores and superiores when the epiphyseal plate develops (Trueta and Harrison, 1953). All arterial rami divide into capillaries which fan out beneath the cartilage surface and reunite in a vein which accompanies the artery.

The terminal divisions of the arterial rami probably play a role in enchondral ossification, for the cartilage around this capillary region presents a granular appearance.

In the late foetal period and the early months of life, an artery extends in the ligamentum capitis femoris, supplying blood to an area as large as that in adults, but an anastomosis with the other vascular systems has not been demonstrated.

II.8.2 *Stage II. Vascularization between 4 months and 3 years*

The most conspicuous change in the vascularization during this period is the disappearance of the vascularization via the ligamentum capitis femoris, although vessels may occasionally still be found in this ligament. At the same time an ossification centre appears at the centre of the femoral head. This ossification centre extends rapidly, and the epiphyseal plate has developed by about the 18th month of life. The ossification centre is vascularized mainly via the laterally entering vessels, which are later called the rami colli et capitis femoris superiores or lateral epiphyseal vessels. The blood vessels enter the femoral head via the outer margin of the epiphyseal plate. From this time on the epiphyseal plate constitutes a barrier to the epiphyseal and metaphyseal vessels, which cannot perforate this plate.

II.8.3 *Stage III. Vascularization between 4 and 7 years*

During this stage, which Trueta calls the intermediate period, many individual variations are observed. Complete organization of the ossification centre in the epiphysis occurs. At this time, this is still vascularized only via the lateral epiphyseal vessels: the rami colli et capitis femoris superiores, which are the distal rami of the medial circumflex femoral artery. According to Trueta the ramus colli et capitis femoris inferioris regress. The ligamentum capitis femoris generally does not yet participate in the vascularization of the femoral head, but marked individual variations exist.

II.8.4 *Stage IV. Vascularization during pre-adolescence, from 7 to 13 years*

The vascularization via the ligamentum capitis femoris develops again, and the contribution of the rami colli et capitis femoris inferiores to the circulation of the epiphysis also increases. The epiphyseal plate constitutes a barrier between the circulation of the epiphysis and the rest of the femur. The two vascular systems persist until organization of the epiphyseal plate is complete. The rami colli et capitis femoris superiores remain the principal nutrient arteries of the femoral head.

II.8.5 *Stage V. Vascularization during adolescence*

The epiphyseal plate begins to close during adolescence. The three vascular systems - the vascularization via the ligamentum capitis femoris and the epiphyseal and metaphyseal vessels - begin to form an entity, and the vascularization of the proximal femur assumes the features also observed in adults.

II.8.6 *Summary*

The proximal femur is vascularized by three different systems which, during the growth of the proximal femur, make different contributions to its circulation. From the 4th month to the 7th year of life the vessels in the ligamentum capitis femoris do not participate in the vascularization of the femoral head. After the 4th year of life the contribution of the metaphyseal vessels diminishes, the femoral head being vascularized only via the lateral epiphyseal vessels and the ligamentum capitis femoris still taking no part. From the 7th year of life, the vessels in the ligamentum capitis femoris resume a role in the vascularization of the femoral head, while that via the metaphyseal vessels still remains limited. The latter vascularization increases toward the end of adolescence. Finally the epiphyseal plate closes and the vessels in the ligamentum capitis femoris constitute an entity with the epiphyseal and metaphyseal vessels: the vascularization of the proximal femur assumes the features also found in adults. The medial and lateral circumflex femoral arteries form the extracapsular vascular ring. At fixed sites, four subsynovial intra-articular arteries arise from this ring and, at the transition from femoral neck to femoral head, form a second, subsynovial intra-articular vascular ring.

CHAPTER III

FRACTURES OF THE PROXIMAL FEMUR

III.1 **Introduction**

For comparison with data in the literature on proximal femoral fractures in children and adolescents, it is necessary to know how the proximal femur is defined and which fractures are counted as proximal femoral fractures. Chapter II has defined which part of the femur is regarded as proximal femur. This chapter presents a survey of the four types of proximal femoral fracture, their aetiology and their clinical features.

III.2 **Classification of proximal femoral fractures**

Fractures of the proximal femur in children and adolescents are classified according to Delbet on the basis of the anatomical localization of the fracture (Colonna, 1929). Four fracture types are distinguished (fig. 4):

- Type I Traumatic separation of the upper femoral epiphysis
- Type II Transcervical fracture
- Type III Basal or cervico-trochanteric fracture
- Type IV Pertrochanteric fracture

Each fracture is specified as displaced or undisplaced. Traumatic separation of the upper femoral epiphysis and transcervical fractures are regarded as intracapsular fractures, while basal fractures and pertrochanteric fractures are regarded as extracapsular fractures.
It is sometimes very difficult to differentiate between transcervical and cervico-trochanteric fractures from "accident radiographs", in which the exact course of the fracture line is not always clear.

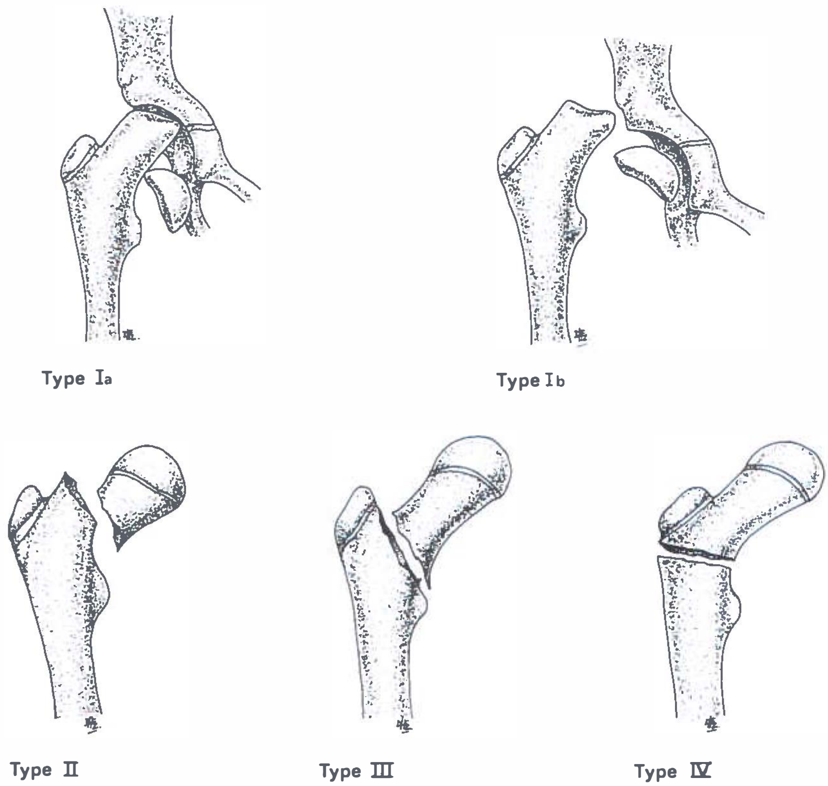


Fig. 4. Classification of proximal femoral fractures according to Delbet.

III.2.1 *Type I. Traumatic separation of the upper femoral epiphysis*

Traumatic epiphysiolysis of the wrist, elbow, ankle and knee is a relatively common injury in children. Traumatic separation of the upper femoral epiphysis (also known as traumatic epiphysiolysis of the hip or epiphyseal fracture of the femoral head), however, is very rare in children (Ratliff, 1968), and seen less often than traumatic hip luxation. It has been maintained (Weber, 1978) that congenital dysplasia of the hip entails an increased risk of traumatic separation of the upper femoral epiphysis due to the changed anatomical relations.

Ingram and Bachynski (1953) maintained that traumatic separation of the upper femoral epiphysis is an "acute traumatic separation of a previously normal epiphysis". The "epiphyseal fracture" does not extend into the metaphysis (Ratliff, 1968; Milgram and Lyne, 1975) but is a displacement which occurs in the epiphyseal plate. Unlike other epiphyseal fractures, therefore, the "fracture" extends through the plane of the epiphyseal plate but does not traverse it and therefore cannot be classified as a fracture. Traumatic separation of the upper femoral epiphysis generally occur in children under age 9 (Ratliff, 1968) and are caused by a severe trauma.

Differentiation between traumatic separation of the upper femoral epiphysis and slipped capital femoral epiphysis can be very difficult in adolescents (McDougall, 1961). Patient with slipped capital femoral epiphysis or imminent epiphysiolysis of the hip often have a long history of vague complaints about the hip, and many have endocrine disorders as well (Burrows, 1957).

A traumatic separation of the upper femoral epiphysis can occur as a complication at delivery (Salter and Harris, 1963; Theodorou et al., 1982). Children and adolescents with a malignancy in the lower abdomen which requires treatment by irradiation, alone or in combination with cytostatics, run an increased risk of slipped capital femoral epiphysis (Chapman et al., 1980; Walker et al., 1981; Wiss and Reid, 1981).

In traumatic separation of the upper femoral epiphysis the proximal fragment - the epiphysis - is as a rule displaced dorsadly. Displacement of the epiphysis from the acetabulum is very rare (Ingram and Bachynski, 1953; Peltokallio and Kurkipää, 1959; Rigault et al., 1966; Fauvy, 1976).

II.2.2 *Fractures of the femoral neck*

The femoral neck is relatively short in children and adolescents, and shows slight anteversion and slight valgus position. In children the trabeculae in the cancellous bone of the femoral neck do not yet follow the force lines, and the cancellous bone is a single dense structure. Comminution (or "Stauchung") of femoral neck fractures is unusual in children and adolescents, but quite common in adults. The firm periosteum surrounding the femoral neck is believed to be responsible for the large percentage of displaced fractures (Craig, 1980).

Basal fractures are more frequently seen under age 13 than above it (Boitzy, 1971). Fractures of the femoral neck which occur after age 13 are more like femoral neck fractures in adults.

Some authors maintain that basal fractures are the most common fractures of the proximal femur in children and adolescents (Haldewang, 1908; Colonna, 1928; Carell and Carell, 1941; Böhler, 1957; Mattner, 1958; Kite et al., 1962). Other authors, however, disagree (Cornacchia, 1951; Lam, 1971; Canale and Bourland, 1977; Ratliff, 1978; Heiser and Oppenheim, 1980; Pförringer and Rosemeyer, 1980).

III.2.2.1 *Type II. Transcervical fracture*

The transcervical fractures include all femoral neck fractures except those localized at the base of the femoral neck where it merges into the trochanteric complex. Unlike adults, children and adolescents have no subcapital proximal femoral fractures.

III.2.2.2 *Type III. Basal or cervico-trochanteric fracture*

Fractures at the level of the transition from femoral neck to trochanteric complex are regarded as basal or cervico-trochanteric fractures, sometimes also known as "hinge fractures". The anatomical and osseous relations at the transition from femoral neck to trochanteric complex might explain the occurrence of fractures at the base of the femoral neck (Schwartz, 1913; Parrini, 1955; Chigot and Estève, 1958).

II.2.3 *Type IV. Pertrochanteric fracture*

Fractures in the very strong trochanteric complex are rare. In children, pertrochanteric fractures are almost as rare as traumatic separation of the upper femoral epiphysis (Schlachetzki, 1930; Ratliff, 1978; Hoekstra, 1982). The fracture line generally extends between the greater and the lesser trochanter, i.e. extracapsularly.

III.3 Aetiology

The occurrence of fractures in the very strong, resilient bone of the proximal femur with its steep CCD-angle requires great forces.
The fracture can be caused by a force acting directly on the greater trochanter or a force acting indirectly, axially, on a preferably rotated femur, or a combination of these forces. It is not inconceivable that torsion also play a role.
In children the CCD-angle is steep. A force acting directly on the greater trochanter causes the CCD-angle to increase. Since the femoral head is fixed in the acetabulum, this results in valgus deformation in the femoral neck, thus giving rise to a basal fracture.
A combination of forces can give rise to a varus deformity in the proximal femur, resulting in a transcervical or basal fracture. This mechanism resembles that involved in adults.

The principal aetiology of proximal femoral fractures in the past involved a fall from a great height (Colonna, 1928; Mitchell, 1936; Wilson, 1940); today, however, road traffic accidents rank first among the causes of proximal femoral fractures (Ratliff, 1978).

III.4 **Clinical signs**

Proximal femoral fractures produce characteristic clinical signs. The fractured leg is shortened and lies in external rotation and adduction. Hip function is impaired, and the hip is painful on passive movement. Sometimes there is a local swelling. The characteristic position of a leg with a proximal femoral fracture is caused by the muscle groups which insert on the proximal femur.
The elevation of the trochanter is caused by the gluteus maximus, adductor, abductor and iliopsoas muscles. The adduction is effected by the iliopsoas, abductor, adductor and gluteus maximus muscles and the external rotators. The iliopsoas, gluteus maximus and external rotator muscles cause the external rotation and prevent anterior or posterior displacement (Kay and Hall, 1971).

III.5 **Radiographic examination**

Radiographic examination can confirm the clinical diagnosis in the acute phase and permits classification by the type of proximal femoral fracture. For this purpose one needs an anteroposterior exposure of the pelvis and supplementary exposures of details of the proximal femur in two perpendicular directions: the so-called Urist and contra-Urist (or $^{3}/_{4}$) projections. Occasionally there may be a need for special exposures in axial projection, or tomography.
The type of proximal femoral fracture and the degree of displacement can thus be determined. For transcervical fractures the degree of displacement is classified according to Garden (1961) at the course of the fracture line according to Pauwels (1935).

III.6 **Summary**

Fractures of the proximal femur are classified into four types:
- Type I Traumatic separation of the upper femoral epiphysis
- Type II Transcervical fracture
- Type III Basal or cervico-trochanteric fracture
- Type IV Pertrochanteric fracture

Traumatic separation of the upper femoral epiphysis and pertrochanteric fractures are both extremely rare. The occurrence of proximal femoral fractures requires very great forces which can act on the proximal femur either directly or indirectly. Due to the anatomical relations in the region of the proximal femur, displaced fractures of the proximal femur produce a characteristic clinical sign: the fractured leg is shortened and lies in external rotation and adduction.

Diagnostic radiography makes it possible to classify proximal femoral fractures by type, and to determine the degree of displacement. In addition, transcervical fractures can be classified according to Garden and Pauwels.

CHAPTER IV

COMPLICATIONS OF FRACTURE HEALING

IV.1 Introduction

Children and adolescents generally develop few complications of fracture healing, with the exception of fractures of the proximal femur. This is explained on the one hand by the anatomical relations and the course of the fracture line, and on the other hand by the way in which the proximal femur is vascularized.

Six complications of fracture healing can be distinguished: avascular necrosis, delayed union and non-union, posttraumatic coxa vara, premature epiphyseal fusion, difference in leg length and arthritis. Several of these complications may occur in combination.

This chapter discusses these six complications of fracture healing.

IV.2 Avascular necrosis

IV.2.1 *Introduction*

Avascular necrosis or posttraumatic ischaemic necrosis of bone can occur anywhere in the skeleton, but the most common localization is the hip. Avascular necrosis of the proximal femur is most likely to occur after intracapsular, displaced fractures of the proximal femur. In adults it is generally limited to the femoral head; in children and adolescents, however, isolated avascular necrosis of the femoral neck can occur. It is caused by disturbances in the vascularization of the proximal femur. During the growth period, the vascularization of the proximal femur develops as described in chapter II. A lesion of the proximal femur can commonly cause disturbances in its vascularization. The occurrence of such disturbances is determined by the type of fracture, presence or absence of displacement, the patient's age, and the time and method of treatment (Boitzy, 1971).

Avascular necrosis occurs more frequently after transcervical than after basal fractures, and more frequently after displaced than after undisplaced fractures of the femoral neck. This applies both to adults and to children and adolescents (Böhler and Ender, 1953; Jantzen and Schuster, 1960; Van der Maes, 1968; Canale and Bourland, 1977; Ratliff, 1978). Revitalization of the osseous tissue after avascular necrosis is believed to be better in children and adolescents than in adults because in the former the bone has greater powers of regeneration due to revascularization (Graham and Wood, 1976). However, if avascular necrosis of the proximal femur occurs in a child or adolescent, then a disturbance in the growth of the proximal femur leads to a disturbance in the development of the hip-joint.

IV.2.2 *Incidence*

Data in the literature on the incidence of avascular necrosis after femoral neck fractures in adults vary widely. Calandruccio and Anderson (1980) found avascular necrosis in 10% of the adults with undisplaced, and in 50% of those with displaced fractures of the femoral neck. Women are believed to run a 150% higher risk of developing avascular necrosis after intracapsular proximal femoral fractures than men (Barnes et al., 1974).
In children and adolescents, too, avascular necrosis of the proximal femur frequently develops after proximal femoral fractures. Again, data on the incidence vary widely, ranging from 13% to 58% (table I). The incidence of avascular necrosis after traumatic hip luxation is about 10% (Klasen, 1978), which is lower than that after fractures of the proximal femur.
Avascular necrosis develops most frequently after traumatic separation of the upper femoral epiphysis and transcervical fractures, and less frequently after basal and pertrochanteric fractures of the proximal femur.

Table 1. Incidence of Avascular Necrosis (AN), Non-Union (NU) and Coxa Vara (CV) after proximal femoral fractures in children and adolescents.

Authors	Age group	N	AN	NU	CV
Carell and Carell (1941)	0-15	12	33%	8%	33%
McDougall (1961)	0-16	24	58%	12%	54%
Weiner and O'Dell (1969)	0-16	23	13%	0%	17%
Lam (1971)	0-17	60	17%	7%	30%
Canale and Bourland (1977)	0-17	61	43%	6%	21%
Ratliff (1978)	0-16	168	46%	10%	15%
Pförringer and Rosemeyer (1980)	0-18	52	28%	11%	6%
Heiser and Oppenheim (1980)	0-18	40	17%	7%	12%
Pathak et al. (1980)	0-18	90	14%	4%	7%

IV.2.3 *Aetiology*

Avascular necrosis of the proximal femur is caused by a disturbance in its vascularization. This can be a primary disturbance due to an accident, or a secondary disturbance as a result of treatment given. The vessels which supply blood to the proximal femur are localized immediately against the trochanteric complex and the femoral neck and head, which give them "protection". With fracture of the proximal femur this "protection" is lost, and a vascular lesion readily occurs. This is more likely to happen with displaced than with undisplaced fractures. Varus displacement of the fracture entails a graver risk of damage to the rami colli et capitis femoris superiores than valgus displacement. The latter, however, causes damage to the less important ramus colli et capitis femoris inferioris. The course of the fracture line is likewise believed to exert an influence on the development of avascular necrosis. Particularly in transcervical fractures of type III according to Pauwels, avascular necrosis is believed to be more frequent than in fractures of type I according to Pauwels (Van der Maes, 1968).

The vascular lesion can consist of complete rupture of a blood vessel, an intimal lesion with secondary thrombosis, or overstretching with or without kinking of the blood vessel. In addition, an intracapsular haematoma may develop. When the intracapsular pressure rises to above the venous pressure, venous stasis occurs. When this situation persists, it may give rise to secondary thrombosis. Salter and Harris (1963) and Woodhouse (1963) observed irreversible changes of the femoral head when an intracapsular pressure in excess of 50-70 mmHg had persisted longer than 10 hours. Soto-Hall (1964) found varying intracapsular pressures with varying positions of the hip. This pressure is highest in adduction, extension and internal rotation, and lowest in flexion, abduction and external rotation.

In displaced fractures the capsule may rupture so that no increased intracapsular pressure can occur. Increased intracapsular pressure caused by a haematoma can readily occur in an undisplaced fracture and in displaced fractures without rupture of the capsule. This prompted Böhler (1956) to state that: "It is rather perplexing to find that even after a fissure of the femoral neck in children avascular necrosis develops".

In conservative treatment of proximal femoral fractures, traction does not ensure adequate immobilization; nor can this be effected by means of a plaster spica. The constant mobility of the two fracture fragments increases the risk of secondary vascular damage. Insufficient traction leads to varus displacement; excessive traction can cause valgus displacement, likewise increasing the risk of secondary vascular damage. The same applies to frequent closed reductions, which can give rise to a vascular lesion or cause aggravation of an existing vascular lesion. In addition, frequent closed reductions can cause damage to soft tissues and thus lead to disturbances in vascalarization.

Operative treatment of proximal femoral fractures likewise entails a risk of avascular necrosis of the proximal femur as a result of peroperative manipulation. Improvements in anatomical knowledge, surgical technique and osteosynthesis material, however, clearly seem to have reduced this risk. Insufficient stability or poor bony contact between the fracture fragments, as seen after non-anatomical reduction, can reduce the revascularization of devitalized bone, thus preventing revascularization of dead bone on the other side of the fracture (Catto, 1976). Proper revascularization requires anatomical fracture reduction and stable fixation. This can also explain the normal union after a femoral neck fracture despite avascular necrosis at the femoral head. Phemister (1915, 1939) described this replacement of dead bone by new bone as "creeping substitution".

The extent to which treatment contributes to the aetiology or to the incidence of avascular necrosis, is still obscure. The difference in final therapeutic results must be ascribed to this (Imhäuser, 1963).

The treatment of these fractures should always aim at prevention of one of the principal complications of fracture healing: avascular necrosis. To begin with, rapid decompression of the joint (within 4-6 hours) is required (Weber, 1982). Open anatomical reduction and internal fixation of the fracture are to be preferred. An alternative which may be considered is puncture of the intracapsular haematoma, postponing definitive treatment to a second session. Only if the above requirements are fulfilled can the risk of avascular necrosis be reduced (Boitzy, 1971; Weber, 1982).

IV.2.4 *Types of avascular necrosis in children and adolescents*

The vascularization of the proximal femur develops during growth, but is provided mainly via the medial circumflex femoral artery, and to a lesser extent via the lateral circumflex femoral artery, the ligamentum teres and the intra-osseous circulation. On this basis, three types of avascular necrosis of the femoral neck and head can be theoretically distinguished (fig. 5). They have been described by Ratliff (1962) and Boitzy (1971) and are derived from the anatomical studies of Trueta (1957). The most widely used classification of avascular necrosis of the femoral neck and head is that introduced by Ratliff (1962). This classification will also be used in this study.

Type of necrosis

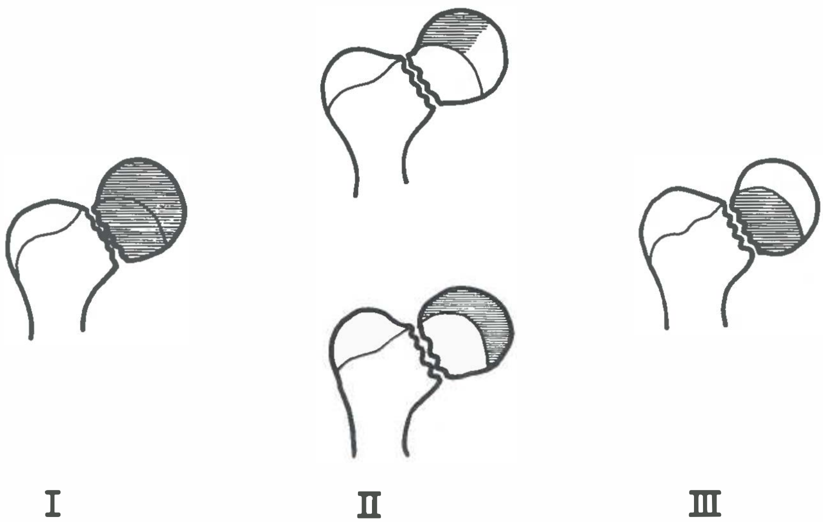


Fig. 5. The three radiological types of avascular necrosis of the femoral head and neck.

TYPE I Avascular necrosis of the femoral head and neck

Avascular necrosis of the femoral head and neck entails a complete disturbance of the vascularization of the head and neck of the femur. The vascular lesion in this case is localized proximal to the division of the epiphyseal and metaphyseal rami, but the necrosis is confined to that part of the proximal femur that is localized cranial to the fracture.

TYPE II Avascular necrosis of the epiphysis

A disturbance in the blood supply to the epiphysis leads to complete or partial avascular necrosis of the epiphysis of the femoral head.

TYPE III Avascular necrosis of the femoral neck

The epiphyseal plate constitutes a boundary between the circulation of the femoral head and that of the femoral neck. A disturbance in the blood supply to the femoral neck results in isolated avascular necrosis of the femoral neck, while the femoral head remains well-vascularized, as does the part of the femoral neck localized distal to the fracture line. This is why isolated avascular necrosis of the femoral neck can occur only in children and adolescents.

IV.2.5 *Clinical symptoms*

Avascular necrosis often entails a disturbance in fracture healing (Santos, 1930). Avascular necrosis generally developed within one year (Lange, 1932; Haase, 1935; Ingram and Bachynski, 1953; Flack and Kudlich, 1962; Ratliff, 1962; Ingelrans et al., 1966). However, in some cases it may not become manifest until years later (Naerra, 1937; Streicher, 1957; McDougall, 1961; d'Aufranc et al., 1962).

The course of the avascular necrosis is characteristic. The complaints are initially not serious but pain, impaired movement and walking problems increase in the course of time.

The avascular necrosis as such is not painful, but pain is caused by collapse of the bone, mostly at the site of maximum weight bearing stress, and on the craniolateral side (Jantzen and Schuster, 1960). Deformation is preceded by flattening of the femoral head (Frangakis, 1966). The subsequent complaints of pain are caused by articular changes which finally become manifest as osteoarthritis of the hip-joint. As a rule there is secondary osteoarthritis on the basis of a deformed femoral neck and/or head. The pain is initially experienced only in movement, but later may be present also at rest.

The impairment of hip movement initially involves limitation of external rotation, followed by limitation of abduction; movements in other directions are not impaired until later.

Disturbances in gait become evident especially when the abductors can no longer function properly. This can be caused by posttraumatic coxa vara or by non-union, resulting in instability of the hip which becomes apparent in a so-called "Trendelenburg gait".

The severe deformations of the hip resulting from avascular necrosis are in part to be ascribed to premature weight bearing while avascular necrosis is developing. After all, avascular necrosis initially causes hardly any complaints and is not demonstrable radiographically (McDougall, 1961). The characteristic radiographic changes do not occur until in a later stage. The density of the avascular bone increases, while the well-vascularized bone shows atrophy of disuse and is therefore relatively decalcified. The articular cartilage, however, remains intact (Santos, 1930; Seddon, 1937).

Avascular necrosis of type I according to Ratliff carries a poor prognosis. In avascular necrosis of types II and III according to Ratliff there is a chance of revascularization.

IV.3 Delayed union and non-union

The term delayed union applies when union fails to occur within 3 months; non-union exists when union fails to occur within 6 months. The term delayed union is an arbitrary one, which cannot be precisely defined. Non-union involves a balance between bone resorption and bone remodelling. The literature indicates a period ranging from 3 months to 5 months for delayed union (Imhäuser, 1963; Ratliff, 1978).
Delayed union and non-union are rare in children and adolescents except after fractures of the proximal femur (Colonna, 1926; Mitchell, 1936). In particular displaced femoral neck fractures and transcervical neck fractures with a Pauwels angle in excess of 50° tend towards non-union (Allende and Lezama, 1951). According to Haddad (1962), basal fractures in particular entail an increased risk of non-union. Delayed union and non-union are reportedly more frequent in conservatively than in operatively treated hip fractures.
The data in the literature on the incidence of non-union after proximal femoral fractures in children and adolescents vary widely, ranging from 0% to 12% (table 1).
Boitzy (1971) distinguishes three types of non-union. Type I is the classical non-union which can also be found elsewhere in the skeleton after a fracture. There is a firm fibrous connection between the two fracture ends, no marked displacement, and vital bone on either side of the fracture. Type II non-union is characterized by marked displacement, absence of a firm fibrous connection, and bone resorption on either side of the fracture. Type III non-union results from avascular necrosis and is seen only in children and adolescents. The avascular necrosis prevents union in these cases.
Non-union can occur after inadequate reduction, insufficient stabilization of a fracture, avascular necrosis and posttraumatic coxa vara (Schwartz, 1914; Ingram and Bachynski, 1953; Allende and Lezama, 1951; Ratliff, 1978). Seddon (1936) thought that delayed union is caused by additional lesions. Interposition of periosteum or capsule can cause delayed union (Miller, 1973).
Generally, however, the cause lies in inadequate treatment (Haddad, 1962; Ricard and Molé, 1965; Delporte, 1966; Ratliff, 1978). Non-union is not an isolated complication of fracture healing, but one that is associated in many cases with other complications such as avascular necrosis and posttraumatic coxa vara.

IV.4 **Posttraumatic coxa vara**

The primary cause of posttraumatic coxa vara is the avascular necrosis, with or without damage to the epiphyseal plate, that can develop after a fracture of the proximal femur. It can give rise to delayed union, non-union and/or disturbed growth of the proximal femur. The continuity of the proximal femoral bone is intact in posttraumatic coxa vara.

Posttraumatic coxa vara is a result of complications of fracture healing after a lesion of the proximal femur, and was already known in the early years of this century (Whitman, 1900; Hoffa, 1903; Haldenwang, 1908); it is a frequent complication after proximal femoral fractures in children and adolescents (McDougall, 1961; Imhäuser, 1963). Mitchell (1935) wrote about posttraumatic coxa vara that: "The unfavourable prognosis associated with this fracture arises from the frequent presence of malunion in coxa vara". Data in the literature on the incidence of posttraumatic coxa vara after proximal femoral fractures in children and adolescents vary widely, ranging from 12% to 54% (table 1).

Clinical examination reveals an elevated trochanter, a shortened leg, impaired hip movement and a positive Trendelenburg sign.

In conservative fracture treatment it is often difficult to obtain and maintain good anatomical reduction, and this applies both to traction and to immobilization in a plaster spica. After insufficient traction and plaster treatment the fracture tends to show varus displacement, while after excessive traction it tends towards valgus displacement, sometimes associated with disturbed rotation.

In addition, conservative treatment of proximal femoral fractures entails an increased risk of non-union and avascular necrosis, and therefore posttraumatic coxa vara. Premature weight bearing after conservative fracture treatment can also cause posttraumatic coxa vara or aggravation of preexistent coxa vara (McDougall, 1961; Imhäuser, 1963; Ricard and Molé, 1965).

Even after adequate anatomical reduction and fixation, posttraumatic coxa vara can develop. In that case the cause lies in insufficient fixation, sometimes in association with avascular necrosis and/or premature epiphyseal fusion. In posttraumatic coxa vara the CCD-angle can be reduced to less than 90° (Strange, 1965).

Posttraumatic coxa vara is slightly less frequent after operative than after conservative treatment of proximal femoral fractures (Ingram and Bachynski, 1953; Ratliff, 1978).

Transcervical fractures with a Pauwels angle in excess of 50° entail a grave risk of non-union and posttraumatic coxa vara (Allende and Lezama, 1951), as compared with basal fractures (Ingelrans, 1959).
In children, slight displacements after fractures are corrected spontaneously, and sometimes even overcorrected. The chance of spontaneous correction of a coxa vara after a proximal femoral fracture, however, is small (Blount, 1955; Miller, 1973; Ratliff, 1978), although it may occur (Lam, 1971; Deluca and Kech, 1976; Ratliff, 1978). In avascular necrosis of the proximal femur and/or ischaemia of the epiphyseal plate, coxa vara may develop but the epiphyseal plate of the greater trochanter as a rule remains intact.
In most cases posttraumatic coxa vara is a result of inadequate treatment (Ratliff, 1978) and due to insufficient reduction, redisplacement of the fracture, delayed union or non-union, avascular necrosis or ischaemia of the epiphyseal plate.
A coxa vara need not be detrimental to the ultimate result, and can be regarded as the least serious complication of fracture healing (Lam, 1971). Only a coxa vara with a CCD-angle of less than 90-110° needs to be considered for corrective osteotomy.

IV.5 Premature epiphyseal fusion

The epiphyseal plate consists of four layers of cells. On its epiphyseal side there is a dormant layer of chondrocytes not involved in growth. The capillaries from the epiphyseal vessels supply this dormant layer of chondrocytes with blood. In the next, germinative layer mitosis of the chondrocytes takes place, and in the hypertrophic layer these cells can continue to grow, whereupon enchondral ossification finally takes place on the metaphyseal side of the epiphyseal plate, which is vascularized by capillaries from the metaphyseal vessels. During growth the epiphyseal plate constitutes a barrier between the two vascular systems, which do not anastomose until the plate disappears (Ham, 1979).
Damage to the epiphyseal plate can give rise to disturbances in proximal femoral growth which become manifest in coxa vara, coxa valga and/or leg shortening. The severity of the growth disturbance depends largely on the patient's age and on the presence or absence of avascular necrosis of the proximal femur.
The proximal epiphyseal plate of the femur contributes little to the longitudinal growth of the femur; in this respect it differs from the distal epiphyseal plate of the femur and the proximal epiphyseal plate of the tibia

(Digby, 1915; Green and Anderson, 1947). This is why severe disturbances in longitudinal growth occur only in young children.
The epiphyseal plate in its totality is no longer supplied with blood when there is damage to both the epiphyseal and the metaphyseal vessels. In that case complete ischaemia of the epiphyseal plate develops and growth ceases. Avascular necrosis of the femoral head and neck develops simultaneously. In these cases, therefore, a disturbance in growth can be the first manifestation of an avascular necrosis (Ratliff, 1962).
When the epiphyseal vascularization is disturbed, mitosis in the germinative layer ceases and most of the chondroblasts die. At the same time, avascular necrosis of the femoral head gradually develops.
When the metaphyseal vascularization is disturbed, the proliferation of cartilage cells remains undisturbed but enchondral ossification is disturbed. When the metaphyseal vascularization is restored, enchondral ossification as a rule resumes, and complete or partial restoration of the growth of the proximal femur results.

Apart from vascular damage, mechanical damage to the epiphyseal plate may occur. In the case of a hip injury this damage can be associated with traumatic separation of the upper femoral epiphysis, axial compression of the epiphyseal plate, or damage to the plate caused by osteosynthesis material. Traumatic separation of the upper femoral epiphysis probably occurs, like any epiphyseal fracture, in the hypertrophic cartilage layer with, as a rule, no damage to the germinative layer (Harris and Hobson, 1956). If there is no associated vascular lesion, then there is a small chance of complete recovery (Ratliff, 1978; Pförringer and Rosemeyer, 1981). Generally, however, traumatic separation of the upper femoral epiphysis is associated with a vascular lesion (Salter and Harris, 1963), and consequently there will be avascular necrosis with premature epiphyseal fusion (Ratliff, 1978; Werkman, 1981; Pförringer and Rosemeyer, 1981).
Another possible cause of mechanical damage is compression of the epiphyseal plate caused by a force acting along the longitudinal axis (Jantzen and Schuster, 1960; Stougard, 1969). Clinical diagnosis of compression of the epiphyseal plate is exceedingly difficult; and this compression is generally not immediately visible on the radiographs. Only at a later age can changes in the epiphyseal plate become apparent: partial or total narrowing of the plate in association with posttraumatic coxa vara or valga.
Transepiphyseally introduced osteosynthesis material can cause premature epiphyseal fusion. This risk prevails even with modern osteosynthesis

material, although total premature epiphyseal fusion is less likely to result. The osteosynthesis material should preferably be introduced parallel. In internal fixation of a proximal femoral fracture in a child or adolescent, the osteosynthesis material should not pass the epiphyseal plate unless this is absolutely necessary to achieve adequate stabilization (Canale and Bourland, 1977).

Premature epiphyseal fusion can be the first sign of an avascular necrosis (Ratliff, 1962). It usually occurs in traumatic separation of the upper femoral epiphysis or in fractures of the femoral neck. The closer the fracture to the epiphyseal plate, the graver the risk of avascular necrosis.

Premature epiphyseal fusion is a manifestation of a very severe trauma, and generally a result of deficient vascularization of the epiphyseal plate or damage to the plate.

IV.6 Difference in leg length

At the end of the growth period the legs are usually of equal length, differences of 1 - 1½ cm being within physiological limits. The extremities grow independently, and growth on one side continues even though growth on the other side is delayed or arrested. There is known regulatory mechanism which could correct a difference in leg length during growth (Sybrandy, 1981).

A difference in leg length after proximal femoral fractures in children and adolescents can result from premature epiphyseal fusion, avascular necrosis of the proximal femur, posttraumatic coxa vara or valga, or non-union (Canale and Bourland, 1977).

After conservative treatment of a proximal femoral fracture in a child or adolescent with a hip spica, premature epiphyseal fusion may occur at the knee and cause a difference in leg length (Ratliff, 1978).

Differences in leg length are not only cosmetic blemishes, but they also exert an unfavourably influence on static relations. The unequal stress on the vertebral column, hip and knee gives rise to arthralgia and, in the long run, can lead to osteoarthritis (Sybrandy, 1981).

IV.7 Arthritis

Fortunately, septic arthritis is a rare complication after proximal femoral fractures; and usually it is iatrogenic. Septic arthritis leads to chondrolysis, necrosis of articular cartillage, of the proximal femur and acetabulum. In addition, this complication in fracture healing can develop as a result of bacteraemia (Lam, 1971; Ratliff, 1978).

Hip function is very poor after septic arthritis, and necrosis of the articular cartillage is bound to lead to osteoarthritis of the hip-joint, with serious complaints.

IV.8 Summary

Six complications of fracture healing can be distinguished: avascular necrosis, delayed union and non-union, posttraumatic coxa vara, premature epiphyseal fusion, difference in leg length and arthritis.
Avascular necrosis of the proximal femur is caused by disturbances in the circulation of the proximal femur. The occurrence of such disturbances is determined by the type of fracture, the presence or absence of displacement, the patient's age and the method of treatment. Three types of avascular necrosis can be distinguished: avascular necrosis of the femoral head and neck (type I), avascular necrosis of the epiphysis (type II), and avascular necrosis of the femoral neck (type III).
The term delayed union applies when no fracture union has occurred within 3 months, while the term non-union is used when no union has occurred within 6 months. Non-union is not an isolated complication of fracture healing but one that is in part caused by other complications such as avascular necrosis and posttraumatic coxa vara.
Posttraumatic coxa vara after a proximal femoral facture is a result of complications of fracture healing. Its primary cause is avascular necrosis, with or without damage to the epiphyseal plate. Coxa vara is believed to be slightly more frequent after conservative than after operative treatment of proximal femoral fractures. It need not have any detrimental effect on the ultimate therapeutic result, and can be regarded as the least serious complication.
Premature epiphyseal fusion can be caused by damage to the epiphyseal plate or a disturbance in its vascularization, and is likely to give rise to disturbances in proximal femoral growth, manifested in changes in the position of the proximal femur and/or a difference in leg length.
A difference in leg length can result from premature epiphyseal fusion, avascular necrosis of the proximal femur, posttraumatic coxa vara or valga, or non-union.
Septic arthritis is a rare complication after a fracture of the proximal femur, and usually iatrogenic; on the other hand, it may develop as a result of bacteraemia. Septic arthritis leads to chondrolysis, necrosis of articular cartilage, of the proximal femur and acetabulum.

CHAPTER V

PATIENTS AND METHOD OF INVESTIGATION

V.1 Patients

The study concerns patients aged 0-18 years, treated for fractures of the proximal femur at the Department of Surgery, Groningen University Hospital, between 1st January 1909 and 31st December 1981 (table 2). Patients with pathological fractures and stress fractures of the proximal femur were not included in this study.
The follow-up was done in 1981. The number of patients was 74, and all had a unilateral proximal femoral fracture. The follow-up period ranged from 5 months to 69 years. Each fracture was given a three-digit number in chronological order (001 through 074).

Table 2. Number of children and adolescents with a proximal femoral fracture per decade.

Period	Number of patients		
	N	♀	♂
1909 - 1920	5	2	3
1920 - 1930	5	1	4
1930 - 1940	8	3	5
1940 - 1950	8	2	6
1950 - 1960	11	2	9
1960 - 1970	18	8	10
1970 - 1981	19	7	12
1909 - 1981	74	25(34%)	49(66%)

V.2 Method of investigation

Per patient, the case history and the radiographs (if available) were studied. The follow-up comprised history, physical examination and radiographic examination. The procedure of follow-up is described in detail in chapter VIII. The data obtained were processed to a punch-card concept and transferred to punch-cards.

The analysis of the data was carried out on a Cyber 170/760 computer at the Computer Centre of the University of Groningen, making use of the statistical programme package WESP (Van der Weele, 1977). The data were processed with the aid of the Schut and Van der Weele protocol (1980). The analysis of the data was exploratory, which is to say that descriptive statistical methods were preferred to the testing of hypotheses. The reason for this was that it is difficult to define a population of which the test group could be considered to be a representative sample, and that generalization of conclusions is consequently precarious.

The difficulty of defining the population has two causes. To begin with, the patients were treated in the course of a long time-span during which circumstances and method of treatment varied considerably; consequently the population for which conclusions can be declared valid, differs.

Secondly, there were very marked interindividual differences in follow-up period, leading to different selections of patients for follow-up examination and therefore to different populations (Visser, 1975). The series was too small to be divided into more homogeneous subgroups without prejudicing the statistical justifiability of conclusions. Formal testing of hypotheses was therefore not justifiable in our opinion. The results of the study and the conclusions based on these results can consequently not be regarded as "statistically proven" but should be formally regarded as "assumptions" to which - with another "sample" - further statistical testing should be applied (Schut and Van der Weele, 1980).

On the basis of medical rationalization and comparison with the literature, we nevertheless believe we can vouch for the validity of our conclusions.

CHAPTER VI

CLINICAL DATA

VI.1 Introduction

Although more than 1000 proximal femoral fractures in children and adolescents have been described since the first publications of Barber (1871) and Cromwell (1885), there are only a few larger series of children and adolescents with proximal femoral fractures (Lam, 1971; Gupta and Chaturvedi, 1973; Talwalker, 1974; Canale and Bourland, 1977; Ratliff, 1978; Pförringer and Rosemeyer, 1980; Pathak et al., 1980).
Only the studies of Boitzy (1971) and Pförringer and Rosemeyer (1977, 1980) distinguish between children and adolescents. Pförringer and Rosemeyer (1980) regard patients up to age 11 as children, and those aged 12 through 18 years as adolescents. We accept this distinction.
So far as possible, the clinical data obtained in this study will be compared with those in the literature.

VI.2 Incidence

Wilson was the first, in 1940, to calculate the incidence of proximal femoral fractures in children and adolescents versus that in adults. During a period of 10 years the General Hospital in Los Angeles treated 600 proximal femoral fractures in adults, and only two in non-adults: a ratio of 1:300. At the Regional Hospital of Central Finland, Peltokallio and Kurkipää (1959) saw only six children and adolescents with a proximal femoral fracture, versus 205 adults: a ratio of 1:34. During the period 1949-1957 the Royal Infirmary in Manchester treated seven children and adolescents with a proximal femoral fracture, versus 900 adults: a ratio of nearly 1:130 (Ratliff, 1962). During the period 1941-1969 Zolcer et al. (1972) treated 3200 femoral neck fractures in adults, and 27 such fractures in age group 13-19. Kovac and

Brandebur (1980) calculated a relative incidence of 1:75; during the period 1955-1978, they saw 1883 proximal femoral fractures in adults, and 25 in children and adolescents.
For some unexplained reason, proximal femoral fractures seem to be more common in Asia than in the western world (Grewal and Charnalia, 1956; Bhansali, 1964; Talwalker, 1974; Pathak et al., 1980). Lam (1976), for example, treated 110 proximal femoral fractures in children and adolescents at the Queen Elisabeth Hospital in Kowloon, Hong Kong, over the period 1961-1974, while over the period 1961-1966 he calculated a relative incidence of 1:19 (Lam, 1967). Gupta and Chaturvedi (1973) calculated the incidence of proximal femoral fractures in children and adolescents versus that in adults at the Medical College of Kanpur (India) over the period 1957-1969, and found the very high ratio 1:10.
Table 3 presents a survey of the incidence of proximal femoral fractures in children and adolescents versus that in adults as indicated in the literature.

Table 3. Incidence of proximal femoral fractures in children and adolescents versus that in adults.

Authors	N	Age group	Incidence
Wilson (1940)	2	0-15?	1:300
Peltokallio en Kurkipää (1959)	6	0-15?	1:34
Ratliff (1962)	7	0-16	1:130
Lam (1967)	49	0-16	1:19
Gupta en Chaturvedi (1973)	74	0-16	1:10
Kovac en Brandebur (1980)	25	0-15	1:75
Hoekstra (1982)	74	0-18	1:36
	65	0-17	1:41
	57	0-16	1:46
	44	0-15	1:61

At the department of Surgery of the Groningen University Hospital, 2632 adults were treated for proximal femoral fracture over the period 1909-1981; 1761 had a femoral neck fracture (67%) and 871 had a pertrochanteric fracture (33%). There were 1454 women (55%) and 1178 men (45%). In the group of children and adolescents (age 0-18) 74 proximal femoral fractures were treated.
During this period the incidence of proximal femoral fractures in children

and adolescents versus that in adults was 1:36 (table 3). In The Netherlands, children and adolescents (age 0-19) account for 31.5% (1 : 3.2) of the total population (Statistical Pocketbook 1981).
A slight seasonal influence on the incidence of these proximal femoral fractures was discernible in a slight predilection for the winter months (table 4).

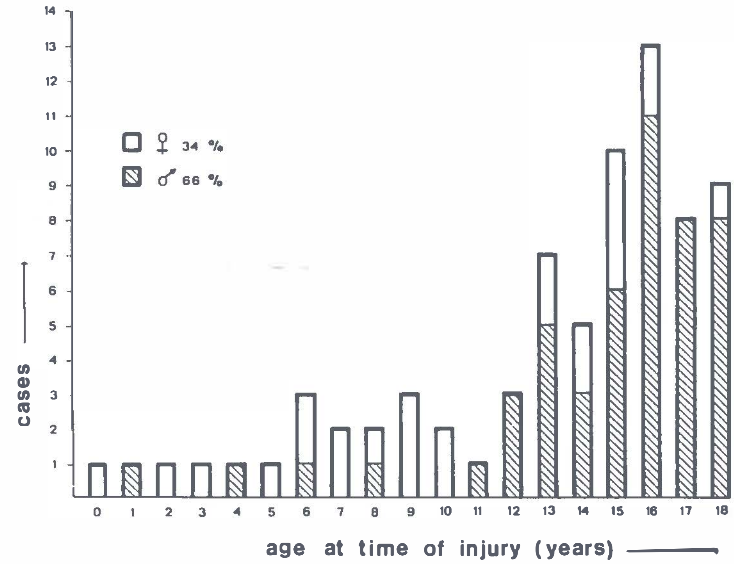
Table 4. Incidence of proximal femoral fractures per month and per season.

Month	N_{74}	Season	N_{74}
December	10		
January	11	Winter	26(35%)
February	5		
March	7		
April	4	Spring	18(24%)
May	7		
June	6		
July	7	Summer	17(23%)
August	4		
September	3		
October	8	Autumn	13(18%)
November	2		

VI.3 Age and sex distribution

Table 5 presents the age and sex distribution of the 74 proximal femoral fractures in children and adolescents. It shows an increase in incidence above age 11, which has also been reported by other authors (Lam, 1967; Canale and Bourland, 1977; Ratliff, 1978; Pförringer and Rosemeyer, 1980; Pathak et al., 1980). However, Talwalker (1974) and Gupta and Chaturvedi (1974) found a high incidence at about age 9 in their series.
A proximal femoral fracture was seen in 25 girls (34%) and 49 boys (66%). Girls with proximal femoral fractures were a minority in the group of adolescents (12-18 years), whereas in the group of children (0-11 years) they were an ample majority.
The male:female ratio was 1 : 2.8 in the group of children and 1 : 0.25 in the group of adolescents. In their series of 51 patients, Pförringer and Rosemeyer (1980) likewise found a higher incidence in girls, the male:female ratio being 1 : 1.6 in the group of children and 1 : 0.38 in the group of adolescents. The sex distribution of proximal femoral fractures in this series is therefore largely dependent on the maximum age for the adolescent group.

Table 5. Age and sex distribution.



A survey of the sex distribution of proximal femoral fractures as found in the literature is presented in table 6. On average, proximal femoral fractures were seen $1\frac{3}{4}$ times as frequently in boys than in girls, whereas in adults they are seen more frequently in women (Jensen, 1980; Lewinnek et al. 1980).

Table 6. Sex distribution of proximal femoral fractures.

Authors	N	Age group	♀	♂
McDougall (1961)	24	0-16	1	2.40
Gupta en Chaturvedi (1973)	74	0-16	1	1.31
Miller (1973)	31	0-17	1	2.10
Talwalker (1974)	100	0-17	1	2.03
Lam (1976)	110	0-16	1	3.12
Canale en Bourland (1977)	61	0-17	1	1.10
Ratliff (1978)	168	0-16	1	1.40
Heiser en Oppenheim (1980)	40	0-16	1	1.43
Pförringer en Rosemeyer (1980)	51	0-18	1	1.21
Hoekstra (1982)	74	0-18	1	1.96
	65	0-17	1	1.71
	57	0-16	1	1.38

VI.4 Cause and site of the accident

Although cause and site of accident are closely correlated, the literature generally mentions only the cause of the accident, but not the site. By mentioning both the cause and the site of the accident, a better understanding of the aetiology of the fracture can be ensured.

VI.4.1 *Cause of the accident*

As already mentioned in chapter III, the occurrence of proximal femoral fractures in children and adolescents requires great direct or indirect forces. These great forces are generally activated only in severe accidents.
Since it is usually impossible to obtain adequate information on the direction of the forces involved, a classification of causes into direct and indirect violence is impossible. Possible, however, is a classification by severity of the accident.
Ratliff (1962, 1978) classified accidents into severe, mild and miscellaneous, and found that 80% of cases involved a severe accident - a conclusion shared by other authors (McDougall, 1961; Papadimitriou, 1966; Canale and Bourland, 1977; Pförringer and Rosemeyer, 1977). On the other hand Gupta and Chaturvedi (1973), Talwalker (1974), Chong et al. (1975) and Pathak et al. (1980) found in their Asian series that a severe injury was involved in less than 50% of the cases, excluding pathological fractures. The authors themselves were unable to explain this, and the question arises whether this patient population can or may be compared with western patient populations.
While in the past a fall from a great height was the principal cause of the accident (Colonna, 1928; Mitchell, 1936; Wilson, 1940; Carell and Carell, 1941), road traffic accidents now rank first (Ratliff, 1978; Pförringer and Rosemeyer, 1977; Craig, 1980). A survey of accident causes is presented in table 7a, while table 7b specifies the road traffic accidents.

Table 7a. Accident causes.

Cause of accident	N_{74}	N_{25} ♀	N_{49} ♂
Road traffic accident	32(43%)	13(52%)	19(39%)
Fall from a height	23(31%)	7(28%)	16(33%)
Fall at home/in the street	8(11%)	–	8(16%)
Fall while skating	6(8%)	3(12%)	3(6%)
Fall while fighting	2(3%)	1(4%)	1(2%)
Miscellaneous	3(4%)	1(4%)	2(4%)

Table 7b. Road traffic accidents.

Road traffic accident	N_{32}	N_{13} ♀	N_{19} ♂
Pedestrian			
collison	7(22%)	3(23%)	4(21%)
Bicycle			
fall	12(38%)	4(31%)	8(42%)
collision	2(5%)	2(15%)	–
Moped			
fall	–	–	–
collision	5(16%)	1(8%)	4(21%)
Motorcycle			
fall	–	–	–
collision	1(3%)	–	1(5%)
Car			
driver	1(3%)	–	1(5%)
passenger	4(13%)	3(23%)	1(5%)

Accident causes were distributed fairly evenly over boys and girls, albeit that none of the girls sustained a proximal femoral fracture by falling on the hip at home or in the street. Falls in the street were caused in three instances by a slippery road surface. Six patients sustained a proximal femoral fracture by a fall on the ice while skating. Such a cause of a proximal femoral fracture was described by Hoffa as early as 1903.
According to the Ratliff criteria (1962) a severe accident was involved in an ample majority of our Groningen cases (75%). Road traffic accidents were the principal cause (43%), followed by falls from a great height (31%). Severe accidents were slightly more often involved in girls (80%) than in boys (71%). Table 8 presents a classification by severity of accident in accordance with the Ratliff classification (1962).

Table 8. Severity of the accident.

Severity	N_{74}	N_{25} ♀	N_{49} ♂
Severe	55(75%)	20(80%)	35(71%)
Mild	15(20%)	3(12%)	12(24%)
Miscellaneous	3(4%)	2(8%)	1(2%)
Unknown	1(1%)	–	1(2%)

VI.4.2 *Site of the accident*

As already intimated, road traffic accidents and falls from a great height ranked first as accident causes (table 7a). Most accidents occurred on the roads (42%), followed by the home (27%), sports and games field (22%) and the working situation (5%). A survey of accident sites is presented in table 9.

Table 9. Accident sites.

Site of accident	N_{74}	N_{25} ♀	N_{49} ♂
Road	31(42%)	12(48%)	19(39%)
Home	19(27%)	5(20%)	14(29%)
Sports field	17(22%)	6(24%)	11(22%)
Work	4(5%)	–	4(8%)
Miscellaneous	3(4%)	2(8%)	1(2%)

VI.5 **Fracture types**

The clinical classification of the fractures is based on the classification of Delbet as described in detail in chapter III. In addition, various fracture types can be classified by sex, age, left-right localization and presence or absence of displacement. In 51 fractures (69%) the epiphyseal plate was open, while in 14 (19%) it had already closed. In 9 fractures (12%) this could not be established with certainty because the radiographs were either of poor quality or no longer available.

VI.5.1 *Age and sex distribution*

Proximal femoral fractures were more frequently seen in adolescents (74%) than in children (26%, table 5). Transcervical fractures (58%) were the most frequently seen proximal femoral fractures, followed by basal fractures (23%), pertrochanteric fractures (16%) and traumatic separation of the upper femoral epiphysis (3%). Pertrochanteric fractures were more frequent in children (83%) than in adolescents (17%). This is in accordance with data from the literature (McDougall, 1961; Miller, 1973; Canale and Bourland, 1977; Heiser and Oppenheim, 1980; Pförringer and Rosemeyer, 1980). A striking finding was that only one of the eight femoral neck fractures in children occurred in a male. The distribution of the fractures types by sex and by children and adolescents is shown in table 10.

Table 10. Distribution of the fracture types by sex and age group.

Fracture type	N_{74}	♀	♂	Children 0-11 yrs N	♀	♂	Adolescents 12-18 yrs N	♀	♂
Type I	2(3%)	1(50%)	1(50%)	1(50%)	1	–	1(50%)	–	–
Type II	43(58%)	13(30%)	30(70%)	5(12%)	5	–	38(88%)	8	30
Type III	17(23%)	5(29%)	12(71%)	3(17%)	2	1	14(83%)	3	11
Type IV	12(16%)	6(50%)	6(50%)	10(83%)	6	4	2(17%)	–	2
		25(34%)	49(76%)	19(26%)	14(74%)	5(26%)	55(74%)	11(20%)	44(80%)

On the basis of the publications of McDougall (1961), Lam (1971), Gupta and Chaturvedi (1973), Talwalker (1974), Canale and Bourland (1977), Ratliff (1978), Pförringer and Rosemeyer (1980) and Heiser and Oppenheim (1980), the distribution of the four fracture types over 596 proximal femoral fractures in children and adolescents was determined. This showed transcervical fractures to be the most common, followed by basal fractures, pertrochanteric fractures and traumatic separation of the upper femoral epiphysis. The same distribution of the four fracture types was found in our Groningen patients (table 11).

Table 11. Distribution of the four fracture types.

Fracture type	Own series N_{74}	Collected series N_{596}
Type I	3%	6%
Type II	58%	50%
Type III	23%	32%
Type IV	16%	12%

VI.5.2 *Left-right distribution*

Proximal femoral fractures were found slightly more often on the left (59%) than on the right (41%), both in children and in adolescents. The sex distribution and the left-right distribution per fracture type were approximately the same. No correlation was demonstrable between dominant body half, fracture cause and fracture localization. Lam (1967) and Gupta and Chaturvedi (1973) in their series likewise found a slight predilection for the left side (70% and 69%, respectively), whereas McDougall (1961) found a slight predilection for the right side (58%). The left-right distribution per fracture type is shown in table 12.

Table 12. The left-right distribution.

Fracture type	N	Left	Right
Type I	2	2(100%)	–
Type II	43	25(58%)	18(42%)
Type III	17	9(53%)	8(47%)
Type IV	12	8(67%)	4(33%)
		44(59%)	30(41%)

VI.5.3 *Displacement*

Displacement was classified as: no displacement (complete bone contact), slight displacement (partial bone contact) and complete displacement (no bone contact), and determined in 57 fractures. Only 11 proximal femoral fractures were undisplaced (19%); 12 showed slight displacement (21%), and the remaining 34 showed complete displacement (60%, table 13a). Undisplaced proximal femoral fractures were found in 33% of the group of children and 14% of the group of adolescents (table 13b).

Table 13a. Displacement according to fracture type.

Fracture type	N	Displacement None	Slight	Complete
Type I	2	–	1(50%)	1(50%)
Type II	35	6(17%)	7(20%)	22(63%)
Type III	10	1(10%)	3(30%)	6(60%)
Type IV	10	4(40%)	1(10%)	5(50%)
	57	11(19%)	12(21%)	34(60%)

Table 13b. Displacement according to fracture type and age group.

Fracture type	Children 0-11 yrs N	Displacement None	Slight	Complete	Adolescents 12-18 yrs N	Displacement None	Slight	Complete
Type I	1(7%)	-	-	1	1(2%)	-	1	-
Type II	4(26%)	1	-	3	31(74%)	5	7	19
Type III	1(7%)	-	-	1	9(22%)	1	3	5
Type IV	9(60%)	4	-	5	1(2%)	-	1	-
	15(26%)	5(33%)	-	10(67%)	42(74%)	6(14%)	12(29%)	24(57%)

Type IV (pertrochanteric) fractures were relatively less often displaced (60%) than the other fracture types. Lam (1971), Canale and Bourland (1977) and Heiser and Oppenheim (1980) likewise found a slightly smaller percentage of displacements (70%) in type IV (pertrochanteric) fractures. As table 14 shows, displacement existed in 68% of the proximal femoral fractures in girls, and in 87% of those in boys.

Table 14. Displacement according to fracture type and sex.

Fracture type	N_{19} ♀	Displacement None	Slight	Complete	N_{38} ♂	Displacement None	Slight	Complete
Type I	1	-	-	1	1	-	1	-
Type II	10	3	-	7	25	3	7	15
Type III	3	-	-	3	7	1	3	3
Type IV	5	3	-	2	5	1	1	3
	19	6(32%)	-	13(68%)	38	5(13%)	12(32%)	21(55%)

The degree of displacement of transcervical fractures as classified according to Garden and Pauwels is shown in table 15. The transcervical fractures were classified according to Pauwels on the basis of the antero-posterior radiograph obtained after reduction.

Table 15. Displacement of transcervical fractures (Type II) as classified according to Garden and Pauwels.

Garden	N_{35}	Pauwels	N_{35}
Garden 1	6(17%)	Pauwels 1	4(12%)
Garden 2	6(17%)	Pauwels 2	26(74%)
Garden 3	2(6%)	Pauwels 3	5(14%)
Garden 4	21(60%)		

So far as available, data from the literature show that about 80% of proximal femoral fractures in children and adolescents are displaced, as indicated in table 16.

Table 16. Percentages of displacement.

Authors	N	Displacement
Lam (1971)	75	76%
Talwalker (1974)	100	95%
Canale en Bourland (1977)	61	79%
Ratliff (1978)	169	75%
Heiser and Oppenheim (1980)	40	70%
Hoekstra (1982)	57	81%

VI.6 Pre-existent diseases

Pathological fractures and stress fractures of the proximal femur were not included in this study. None of the patients had pre-existent lesions of the proximal femur or hip-joint. A pre-existent disease was present in only 4 patients (5%). In all these cases this had been of influence in the aetiology of the proximal femoral fracture, as the following four case histories demonstrate.

Nr. 041 A 15-year-old palsied, retarded boy suffering from epilepsy fell from his bed and subsequently complained of pain in the left hip. Since he had hardly been able to walk even before the fall, he was not referred to a hospital until 12 days later. Examination revealed a transcervical fracture with slight displacement.

Nr. 042 A 14-year-old boy with marked mental and motor retardation as a result of tuberculous meningitis, fell on the right hip during an epileptic seizure. Walking had been difficult even before the fall, and he was not referred to a hospital until 4 days later. Examination revealed a completely displaced transcervical fracture.

Nr. 053 After amputation of the left lower leg necessitated by posttraumatic osteitis, an 18-year-old boy was admitted to a rehabilitation centre and fell on the left hip while trying to walk with crutches. He sustained a transcervical fracture.

Nr. 069 An autistic 2-year-old girl fell from a window at a height of 3 metres and sustained injuries of the right hip, head and left shoulder and elbow. Examination revealed an undisplaced pertrochanteric fracture.

VI.7. Concomitant lesions

From one to three concomitant lesions were present in 21 cases (28%). Concomitant lesions were more frequently found in females (36%) than in males (24%), as shown in table 17.

Table 17. Concomitant lesions.

Concomitant lesions	N_{74}	N_{25} ♀	N_{49} ♂
Present	21(28%)	9(36%)	12(24%)
Absent	53(72%)	16(64%)	37(76%)

The presence or absence of concomitant lesions depends on the severity of the accident and, therefore, generally on the cause of the accident. Particularly road traffic accidents and falls from a great height account for concomitant lesions (table 18), which mainly involved the extremities, the pelvis and the head (table 19). The literature indicates that about 25% of proximal femoral fractures in children and adolescents are associated with concomitant lesions (table 20). Rare concomitant lesions are contralateral proximal femoral fractures (Kaposi, 1926; Carell and Carell, 1941; Weiner and O'Dell, 1969; Canale and Bourland, 1977; Ratliff, 1978; Pförringer and Rosemeyer, 1980), and homolateral fractures of the femoral shaft (McDougall, 1961; Fardin, 1970; Hoeksema et al., 1975; Hoekstra, 1982).

Table 18. Accident cause and prescence of concomitant lesions.

Accident	N	Concomitant lesion Present	Absent
Fall	8	–	8
Accident to pedestrian	7	6	1
Fall from bicycle	12	–	12
Accident to cyclist	2	2	–
Fall from moped	–	–	–
Accident to driver of moped	5	2	3
Fall from motorcycle	–	–	–
Accident to driver of motorcycle	1	–	1
Accident to cardriver	1	–	1
Accident to carpassenger	4	2	2
Fall from a height	23	9	14
Miscellaneous	11	–	11
	74	21(28%)	53(72%)

Table 19. Localization of concomitant lesions.

Cause of accident		Head	Thorax	Abdomen	Pelvis	Upper extremity	Lower extremity
Road traffic accident	N_{32}	5(16%)	3(9%)	1(3%)	6(19%)	3(9%)	6(19%)
Fall from a height	N_{23}	1(4%)	–	–	4(17%)	7(30%)	1(9%)
Other type of accident	N_{19}	–	–	–	–	–	–
Accident	N_{74}	6(8%)	3(4%)	1(1%)	10(14%)	10(14%)	7(9%)

Table 20. Percentage of concomitant lesions.

Authors	N	Concomitant lesions
McDougall (1961)	24	17%
Lam (1971)	75	26%
Gupta en Chaturvedi (1973)	74	23%
Hoekstra (1982)	74	28%

VI.8 Summary

Data in the literature on the incidence of proximal femoral fractures in children and adolescents versus that in adults, vary very widely. In this study the incidence in children and adolescents, which largely depends on the maximum age for the group of adolescents, was 1:36, which is distinctly higher than that reported by Ratliff (1962) and generally accepted in the literature: 1:130. Proximal femoral fractures were more frequently seen in adolescents (74%) than in children (26%) and were about $1\frac{3}{4}$ times as frequent in males as in females, but in this respect it is to be noted that the group of children (0-11 years) included more females than males with a proximal femoral fracture.

The cause of the proximal femoral fracture in 75% of cases was severe violence produced by a road traffic accident or a fall from a great height. Type II (transcervical) fractures were the most common type of proximal femoral fracture (58%), followed by type III (basal) fractures (23%), type IV (pertrochanteric fractures (16%) and type I (traumatic separation of the upper femoral epiphysis) in 3% of cases. Proximal femoral fractures were slightly more often localized on the left (59%) than on the right side (41%). About 80% of the proximal femoral fractures were displaced, displacement being observed slightly less often in girls (68%) than in boys (87%). Pertrochanteric fractures showed displacement slightly less often (60%) than the other fracture types, and these fractures were more common in children (83%) than in adolescents (17%).

A concomitant lesion was present in 28% of the patients, and was found more often in girls (36%) than in boys (24%). Concomitant lesions occurred only in road traffic accidents or a fall from a great height and mainly involved the extremities, the pelvis and the head.

CHAPTER VII

TREATMENT

VII.1 Introduction

In the past, fractures of the proximal femur in children and adolescents were treated conservatively. In the course of the years, however, emphasis has shifted from conservative to operative treatment. The literature shows that most series of children and adolescents with proximal femoral fractures are small, and include a variety of methods of treatment.
This chapter presents a review of the historical development of the treatment of proximal femoral fractures in children and adolescents and discusses indications for conservative or operative treatment. It then describes the methods of treating various complications of fracture healing. Finally it presents a survey of the methods of treatment of proximal femoral fractures in children and adolescents used in the Groningen patients, so far as data could be obtained from the medical records.

VII.2 Review of the historical development of various methods of treatment

At the end of the 19th and in the early years of the 20th century, publications on proximal femoral fractures in children and adolescents were as a rule merely single or collected case reports (Barber, 1871; Cromwell, 1885; Russell, 1898; Hoffa, 1903; Hesse, 1905; Noble, 1907; Haldewang, 1908; Borchard, 1909; Lombard, 1910; Schwartz, 1913; Taylor, 1917; Bland-Sutton, 1918; Greig, 1919; Nicolas, 1922). Whitman (1891, 1893, 1897, 1900, 1909) treated 31 proximal femoral fractures in children and adolescents, and his publications are of great historical value.

Traction is the oldest method of treating proximal femoral fractures. The studies of Royal Whitman, however, marked the first progress in the treatment of proximal femoral fractures, in children as well as in adolescents. In 1898 this author introduced abduction treatment of proximal femoral fractures with the aid of a plaster spica. The fracture was reduced by abduction and internal rotation of the fractured limb under traction, and subsequently the limb was immobilized in extension, maximal abduction and internal rotation in a plaster spica. This hip spica, to which Whitman's name was later attached, has long been used in the treatment of proximal femoral fractures in children and adolescents as an alternative to treatment by traction in abduction.

Both methods give rise to complications of fracture healing manifested as coxa vara, difference in leg length and reduced mobility of the hip-joint. Borchard (1909) suggested that extirpation of the femoral head should be resorted to after an unsuccessful attempt to treat a proximal femoral fracture, and Worms and Hamant (1912) also recommended this.

Colonna (1926), Mitchell (1936), Wilson (1940) and Carell and Carell (1941) used a Whitman cast in the treatment of these fractures. They concluded, however, that immobilization was insufficient. Mitchell (1936) and Carell and Carell (1941) contended that better immobilization could be achieved by traction in abduction and a plaster spica. Böhler (1935), on the other hand, advised treatment by traction only.

Operative treatment by internal fixation of proximal femoral fractures in adults was described even in the 19th century (Von Langenbeck, 1878; Nicolaysen, 1897). In imitation of Nicolaysen (1897), who used a "nail" in fracture fixation, Delbet (1920) introduced a screw. Other forms of fixation (e.g. with an ivory pin) were also used. In 1931 Smith-Petersen introduced the flanged nail which was to become known as Smith-Petersen nail in the treatment of this type of fracture in adults; Johnsson (1932) later modified this nail. In 1936 Knowles introduced the Knowles pins, besides which three other pins are known: Moore pins, Haggie pins and Steinman pins. Knowles pins have a screw thread proximally, and Moore pins have one at the distal end. Haggie pins have screw threads at both ends, and Steinman pins have no screw thread.

Fixation of proximal femoral fractures with a flanged nail or some other type of nail reduced complications of fracture healing in adults.

In view of the encouraging results of operative fracture treatment in adults and the poor results of conservative fracture treatment in children and adolescents, operative treatment was gradually accepted in the latter group. Initially, it was sometimes combined with a hip spica.

An ivory pin or a "nail" have not been used in the treatment of proximal femoral fractures in children and adolescents, but the use of a Smith-Petersen nail has been reported. The Smith-Petersen nail or other flanged nail types are unsuitable for use in children and adolescents, whose bones are much harder than those of adults. Insertion of the nail therefore requires considerable force and entails the risk that the proximal fragment may be carried forward with the nail, resulting in distraction of the fracture, or even that the proximal fragment splits (McDougall, 1961; Lam, 1964; Strange, 1965). Another risk is rotation of the proximal fragment (Müller, 1974). This risk is smaller in stable fractures, and can be avoided by passing a Kirschner wire through both fracture fragments.
The femoral neck is narrow and has a physiological curvature, which impedes insertion of the nail (Sullivan, 1953; Boitzy, 1971). If a flanged nail is nevertheless used for fracture fixation, then this should be done very cautiously to avoid damage to the epiphyseal plate (Wilson, 1940; Streicher, 1957).
Unlike the Smith-Petersen nail, the Knowles pins or other types of pin can be inserted without difficulty and ensure adequate fixation of the proximal fragment, while at the same time causing little damage to the epiphyseal plate (Ingram and Bachynski, 1953; Parrini, 1955; McDougall, 1961; Imhäuser, 1963; Titze, 1968).
Particularly in the German literature, treatment of proximal femoral fractures in children and adolescents by screw osteosynthesis or Kirschner wire fixation has been advocated (Boitzy, 1971; Miller, 1973; Pförringer and Rosemeyer, 1977, 1980).
Indications for the use of a flanged nail in the treatment of proximal femoral fractures in children and adolescents are no longer recognized today (Strange, 1965; Manninger, 1981).

Gradually, a method of treating proximal femoral fractures in children and adolescents evolved on the basis of experience gained in the conservative and operative treatment of various types of proximal femoral fractures. Since the introduction of surgery in the treatment of these fractures in children and adolescents, the advantages and disadvantages of the two methods have been under discussion. All authors agree that pertrochanteric fractures in children and adolescents can as a rule be treated conservatively without undue problems.
Even when more experience was gained in operative fracture treatment, better osteosynthesis materials became available and fewer complications

occurred, some authors remained advocates of conservative treatment (Green, 1953; Böhler, 1957; Streicher, 1957; Kite et al., 1962). Peltokallio and Kurkipää (1959), Flach and Kudlich (1962) and Feigenberg et al. (1977) preferred treatment in traction. Rigault et al. (1966) maintained that good, stable reduction can certainly be achieved with a hip spica. Ratliff (1962) and Lam (1971) also treated undisplaced proximal femoral fractures with a hip spica.

Other authors held the indication for conservative treatment of a proximal femoral fracture to be dependent on the patient's age, the type of fracture, the degree of displacement and the reduction achieved (Ingram and Bachynski, 1953; Speed and Knight, 1956; McDougall, 1961; Hamilton, 1961; Aufranc et al., 1962; Chigot and Vialas, 1963; Rigault et al., 1966; Ingelrans et al., 1966; Rettig, 1968; Jungbluth et al., 1968; Titze, 1968; Lam, 1971; Miller, 1973; Chong, et al., 1975; Ratliff, 1978). Allende and Lezame (1951) advised conservative treatment (with a hip spica) for femoral neck fractures with a Pauwels angle of less than 50°; in patients with a Pauwels angle in excess of 50° and slight displacement they performed an intertrochanteric osteotomy; in patients with a Pauwels angle in excess of 50° and marked displacement they combined the osteotomy with transplantation of a fibular graft.

The advocates of operative treatment of proximal femoral fractures in children and adolescents included Dickson (1948, 1953), Moser (1949), Ingram and Bachynski (1953), Sullivan (1953), Mattner (1953), McDougall (1961), Kite et al. (1962), Imhäuser (1963), Titze (1968), Boitzy (1971), Kay and Hall (1971), Solheim (1972), Nöh and Rettig (1974), Ratliff (1978), Heiser and Oppenheim (1980), Quinlan et al. (1980), Pförringer and Rosemeyer (1980) and Böhler (1981). Imhauser (1963) pointed out the unphysiological extension of the hip in a hip spica and the risk of premature distal and proximal epiphyseal fusion with this method, and preferred operative treatment.

The opponents of operative fracture treatment have always pointed out the numerous complications observed after this type of treatment (Wilson, 1940). More specifically they mentioned the risk of premature epiphyseal fusion and the development of avascular necrosis. In conservatively treated proximal femoral fractures, however, the number of complications was likewise very large (Colonna, 1929; Mitchell, 1936; Ingram and Bachynski, 1953; Kay and Hall, 1973). With the improved operative techniques, osteosynthesis materials and insight into the fractures of the proximal femur, these complications seem to have decreased in operatively treated fractures. After internal and transepiphyseal fixation of proximal femoral fractures there is still a risk of avascular necrosis or damage to the epiphyseal plate resulting in premature fusion (Wilson, 1940; McDougall, 1961; Bester, 1967). Moser (1949) and Mattner (1958) maintained that precisely as a result of internal fixation granulation tissue from the femoral neck might grow into the femoral head, thus ensuring better vascularization. Damage to the epiphyseal plate was reportedly reduced by the use of Kirschner wires, screws and Knowles pins (Rehbein and Hofman, 1963; Pförringer and Rosemeyer, 1977).

VII.3 Indications for conservative or operative treatment

The indication for conservative or operative treatment of proximal femoral fractures in children and adolescents depends on the type of fracture, the patient's age and concomitant lesions, if any.

It may be very difficult to achieve anatomical reduction of a displaced proximal femoral fracture by closed reduction. This is usually due to anatomical relations and the often sharp fracture surfaces. Moreover, periosteum or - in intracapsular fractures - part of the joint capsule may be incarcerated between the two fracture fragments. And repeated closed reduction of displaced proximal femoral fractures entails a risk of causing or aggravating a vascular lesion of the proximal femur (Peltokallio and Kurkipää, 1959; Imhäuser, 1963). It may also be very difficult to maintain an adequate reduction in conservatively treated proximal femoral fractures. One of the principal indications for operative fracture treatment is in fact the prevention of such complications as non-union and coxa vara, which frequently develop after conservative fracture treatment (Ingram and Bachynski, 1950; Imhäuser, 1963).

In traumatic separation of the upper femoral epihysis and in intracapsular fractures there is a risk of development of an intracapsular haematoma. This intracapsular haematoma can lead to venous stasis and, if increased intracapsular pressure persists, to avascular necrosis of the femoral head (Salter and Harris, 1963; Woodhouse, 1963). The treatment of these fractures in children and adolescents is therefore an "indicatio vitalis".

Pertrochanteric fractures and undisplaced basal fractures in children can as a rule be treated conservatively. In adolescents, however, operative treatment is to be preferred for basal fractures. All other fractures of the proximal femur carry an indication for operative treatment (Boitzy, 1971). If surgery is not immediately possible, traction in extension and abduction and puncture of the intracapsular haematoma (if any) suffice initially. Traction should amount to one-fifth of the body weight to prevent vascular thrombosis (Müller, 1974). The operation can then be performed in a second session.

VII.4 **Conservative treatment**

The range of indications for conservative treatment is limited to pertrochanteric fractures and sometimes includes undisplaced basal fractures in children.

Three types of conservative treatment can be distinguished:
— hip spica
— traction
— combination of hip spica and traction.

VII.4.1 *The hip spica*

The hip spica or Whitman cast has already been described in section 2 of this chapter. It is difficult to maintain fracture reduction and the position of the femur in the hip-joint is unphysiological (Carell and Carell, 1941; Streicher, 1957; Mattner, 1958). This applies, not only to the Whitman cast or single hip spica but also to the double hip spica, the one-and-a-half spica and the Well-leg Traction Cast or Martin-Hooke cast. This method of treatment entails a large number of complications of fracture healing: avascular necrosis of the proximal femur, non-union, coxa vara and decubitus of the skin can develop. Another possible complication is the development of the so-called cast syndrome: skeletal atrophy, diminished peripheral circulation and joint stiffness (Wilson, 1940; Chigot and Davy, 1958; Mattner, 1958; Chung, 1981). Consequently the hip spica no longer plays a role of significance in the conservative treatment of proximal femoral fractures.

VII.4.2 *Traction*

Continuous traction on the femur via a proximal tibial or supracondylar Denham nail or adhesive plaster extension bandage in extension and abduction is a better method of conservative treatment. Adhesive plaster traction on the other leg is preferably used as countertraction. Treatment in traction ensures a more physiological position of the femur. With this method, too, there are many complications of fracture healing, mainly avascular necrosis of the proximal femur, non-union and coxa vara (Carell and

Carell, 1941; Streicher, 1957; Mattner, 1958). Unlike the hip spica, treatment in traction has a range of indications, mainly for pertrochanteric fractures and sometimes for undisplaced basal fractures.

VII.4.3 *Combination of hip spica and traction*

Combined treatment with hip spica and traction is reported to ensure better immobilization of the proximal femoral fracture and, therefore, to be less likely to entail complications of fracture healing (Carell and Carell, 1941; Parrini, 1955). Peltokallio and Kurkipää (1959) prescribed six weeks of traction to begin with, followed by six weeks of combined treatment with hip spica and traction. Ingram and Bachynski (1953) advised a Martin-Hooke cast and traction or only a Whitman cast for undisplaced fractures. For the same reasons as those listed for the hip spica, this combined treatment is no longer of significance in the treatment of proximal femoral fractures.

VII.5 Operative treatment

Operative treatment should preferably take place within 4-6 hours (Weber, 1982). Anatomical reduction of the proximal femoral fracture can be achieved by open reduction. In the case of intracapsular fractures, this requires opening of the joint capsule; but when this is done on the anterior side there is no risk of a secondary iatrogenic vascular lesion. An intracapsular haematoma, if present, can be drained and the fracture can be reduced under direct vision. Suitable for operative treatment are in particular traumatic separation of the upper femoral epiphysis, transcervical fractures and displaced basal fractures. Although initially operative treatment was sometimes combined with the use of a hip spica, there is no longer any indication for this combined treatment.

The osteosynthesis materials suitable for internal fixation are cancellous bone screws, pins and Kirschner wires.

VII.5.1 *Cancellous bone screws*

Screw ostesynthesis is preferably performed with the aid of cancellous bone screws, of stainless steel or of vitallium. The disadvantage of vitallium screws is that it is often difficult to remove them after fracture healing. Cancellous bone screws are available in several lengths, diameter and thread length.

VII.5.2 *Pins*

The pins which Knowles introduced in 1936 are chromium-plated steel pins of varying lengths, with a sharp point and a screw thread at the proximal end. A ring on the pin prevents it from being screwed in too far. Moore pins, on the other hand, have a screw thread at the distal end, and according to Lam (1967) are more satisfactory because they ensure better fixation. There are no indications for the use of Haggie pins and Steinman pins in the treatment of proximal femoral fractures in children and adolescents. Slipped capital femoral epiphysis constitutes the special indication for the use of Knowles pins. Butler and Cary (1971) advised that the pins should preferably be inserted parallel.

VII.5.3 *Kirschner wires*

Internal fixation of the proximal femur can be achieved also with thick Kirschner wires, but is less stable than that achieved with cancellous bone screws and Knowles pins (Hofmann, 1964; Boitzy, 1971). Pförringer and Rosemeyer (1977, 1980) reported favourable results obtained by Kirschner wire fixation of proximal femoral fractures.

VII.6 **The operation**

As already mentioned, proximal femoral fractures in children and adolescents constitute an urgent indication for operation. The operation can be divided into three phases on the basis of current view on the pathophysiology of fracture healing, treatment and postoperative management.

— Drainage of the intracapsular heamatoma.
— Fracture reduction.
— Maintenance of reduction.

The patient is placed supine on an extension-type operating table. Two X-ray image intensifiers are preferably used during the operation. The approach is made via a lateral longitudinal Watson-Jones incision (1936) between the tensor fasciae latae muscle and the gluteus medius muscle. The vastus lateralis muscle is then mobilized lateradly and, if necessary, the joint capsule is opened via a T-shaped incision on the anterior side. The haematoma in an intracapsular fracture, which is usually under tension, can be drained and the joint washed out. The fracture is then reduced under direct vision and provisionally fixed with Kirschner wires. The reduction is verified with the aid of the image intensifiers. Definitive internal fixation can then be effected with cancellous bone screws or Knowles pins. Dependent on the type of fracture, the screw thread of these pins should preferably not pass the epiphyseal plate but fix only the cranial fragment, because otherwise it is impossible to achieve compression on both fragments. Dependent on the patient's age and the type of fracture, one to three screws are inserted, preferably parallel. A Redon vacuum drain is left in situ to drain the joint cavity during the first 48 postoperative hours.

VII.7 Postoperative treatment

In order to prevent external rotation of the femur and to ensure optimal relief of the hip-joint, a balance traction is applied for 10-14 days. Non-weightbearing exercises and active muscle exercises can be started after 14 days. As soon as muscular control is recovered, non-weightbearing mobilization can be started. This, however, depends on the patient's age and the degree of cooperation to be expected.
Further management depends on the clinical and radiological findings. If no complications of fracture healing occur the patient can as a rule be fully ambulated after 3-6 months, dependent on his age and the type of fracture. The osteosynthesis material should preferably be removed after 18-24 months. If complications of fracture healing develop, then the further strategy is determined by these complications.

VII.8 Treatment of complications of fracture healing

The treatment of complications of fracture healing is largely determined by individual factors, the type of complication, the associated symptoms, and the long-term or short-term prognosis. The various complications of fracture healing and their treatment are discussed in the following subsections.

VII.8.1 *Avascular necrosis*

There is as yet no satisfactory surgical treatment for the complication described as avascular necrosis or posttraumatic ischaemic necrosis of the proximal femur in children and adolescents. Both the fractures and the avascular necroses are classified according to Ratliff (1962), as indicated in figures 4 and 5. A treatment programme is designed on the basis of this classification, previous treatment, and existing complaints. Prolonged relief of the hip-joint is the primary requirement. The duration of this relief depends on the clinical and radiographic findings. Any load on the hip-joint

entails the action of mechanical forces on the proximal femur. They may impede "revascularization" and thus lead to deformation of the proximal femur and possibly to delayed union, non-union or coxa vara.
Although relief of the hip-joint in the mechanical sense is required, frequent non-weightbearing mobilization is required to counteract atrophy of muscle and bones and prevent necrosis of the articular cartilage.

Type I avascular necrosis according to Ratliff (complete avascular necrosis of the femoral head and neck) gives rise to a totally deformed proximal femur and, at a later age, results in severe osteoarthritis of the hip-joint. Sooner or later, surgical treatment will be necessary. Although enormous progress has been made in surgery of the hip, corrective osteotomy or arthrodesis is to be preferred for juvenile and young adult patients in this situation, while the possibility of total hip replacement is to be considered for patients of more advanced age.
The therapeutic possibilities in partial or total avascular necrosis of the femoral head (Ratliff type II) are the same as those in type I according to Ratliff.
Avascular necrosis of the femoral neck (Ratliff type III) is highly specific for children and adolescents and never observed after proximal femoral fractures in adults. In this type of avascular necrosis in particular there is a possibility of revascularization of the femoral neck (Ratliff, 1978), even though premature epiphyseal fusion may interfere with the growth of the proximal femur.
For this revascularization and remodelling of bone, two requirements must be fulfilled: good reduction and internal fixation of the fracture. If these requirements are met, then remodelling of bone can generally be expected after prolonged non-weightbearing mobilization (Ratliff, 1978).
In the treatment of avascular necrosis of the proximal femur in children and adolescents, no experience has so far been gained with pedicled bone grafts (Judet et al., 1981), grafts of cancellous bone and bone chips (Judet, 1961; Rigault et al., 1966), or rotation osteotomies of the kind described by Sugioka (1978) for young adults with idiopathic avascular necrosis of the femoral head.

VII.8.2 *Non-union*

Fracture union may be delayed or entirely absent. The treatment of non-union of fractures of the proximal femur in children and adolescents is difficult and depends on the fracture type, the type of non-union and the previous

treatment. For the treatment of a classical non-union (Boitzy type I) and for that of posttraumatic coxa vara, intertrochanteric abduction osteotomy would seem to be an excellent choice (Carell and Carell, 1941; McDougall, 1961; Chong, 1975; Ratliff, 1978). The purpose of this osteotomy is to improve the mechanical relations by making the fracture line more horizontal. This osteotomy was described by Hoffa as early as 1903, and subsequently studied in detail by Pauwels (1935, 1949). Another possibility is the use of a cancellous bone graft, with or without osteotomy (Boitzy, 1971). This treatment requires good internal fixation of the non-union.
The treatment of Boitzy type II and type III non-union is extremely difficult due to the presence of avascular necrosis. Treatment should therefore aim at restoration of the vascularization of the avascular bone. Revascularization is possible after good internal osteosynthesis (creeping substitution), grafting of cancellous bone or a tibial graft (Judet, 1961; Rigault et al., 1966), and possibly after a pedicled bone graft (Judet et al. 1981).
In the operative treatment of non-union the fracture must be brought to view and good internal fixation must be achieved. This always entails a risk of damage to the vascularization of the proximal femur.

VII.8.3 *Posttraumatic coxa vara*

This frequently observed complication seldom causes complaints; only if the CCD-angle is less than 90-100° should a corrective osteotomy be considered.

VII.8.4 *Premature epiphyseal fusion*

There is no treatment for preventing premature epiphyseal fusion. This complication gives rise to growth disturbances which can lead to deformation of the femoral head and neck, and to a difference in leg length. Sooner or later the deformed proximal femur leads to osteoarthritis of the hip-joint. Depending on the patient's age, the severity of the complaints and previous treatment, this will require arthrodesis or arthroplasty. When the deformity of the hip is strictly localized, a derotating and/or corrective osteotomy may suffice.

VII.8.5 *Difference in leg length*

A difference in leg length can be caused by a growth disturbance in the proximal or the distal femur, posttraumatic coxa vara or valga, or avascular necrosis. Moreover, physiological correction of leg length can occur in one of the legs. Differences in leg length of up to 1½ cm can be overcome by raising the heel. Correction of larger differences requires that the sole as well as the heel of the shoe be raised. Surgical correction can be considered if the difference in leg length is 3-4 cm or more.

Depending on the patient's age, habitus and current growth phase, there are three possibilities:

— Surgical shortening of the longer leg.
— Surgical lengthening of the shorter leg.
— Procedures to delay the growth of the longer leg.

Of these three possibilities, surgical lengthening is technically difficult and time-consuming. Surgical shortening alters the proportional dimensions. Delaying growth by means of epiphysiodesis is a fairly simple procedure, and the ultimate result is fairly accurately predictable (Phemister, 1933; Green and Anderson, 1957; Sybrandy, 1968). For older patients, shortening osteotomy of the contralateral leg is to be preferred to lengthening of the homolateral leg.

VII.8.6 *Arthritis*

A very serious complication is septic arthritis. Treatment consist of removal of necrotic bone and drainage of the hip-joint. Surgical treatment is supported by antibiotics. The septic arthritis leads to necrosis of the articular cartilage and mostly to spontaneous ankylosis.

VII.9 **A survey of the methods of treatment used in the Groningen patients**

A detailed survey of the development of various methods of treatment has been presented in an earlier section of this chapter. This development also emerges from a study of the data on the Groningen patients.

The proximal femoral fractures were initially treated conservatively. Operative treatment was not infrequently resorted to when complications of fracture healing develop. Encouraged by the good results of the operative treatment of proximal femoral fractures in adults, the indications in children and adolescents likewise shifted from conservative to operative treatment. In the early phase of this development, complications of operative treatment sometimes necessitated a return to conservative treatment. A survey of the treatments of the Groningen patients is presented in table 21.

Table 21. Treatment

Treatment	N_{74}
Conservative	32(43%)
Conservative - operative	10(14%)
Operative	27(36%)
Operative - conservative	4(5%)
Miscellaneous	1(2%)

The primary treatment was conservative in 42 patients. In view of complications, surgery was resorted to in 10 patients (24%). Primary operative treatment was performed on 31 patients; in only 4 patients (13%) did complications of operative treatment necessitate recourse to conservative treatment.

A total of 14 patients (19%), therefore, developed complications of treatment or fracture healing which made it necessary to change the form of treatment. A type II (transcervical) fracture was involved in 13 cases (93%), while a type III (basal) fracture was involved in only one case (7%). Poor reduction necessitated a change in the method of treatment in 7 of the conservatively treated patients, and delayed union did in 3 patients. In the surgical group, failure of the operation necessitated recourse to conservative treatment in 2 cases, and insufficient fracture reduction after internal fixation did in 2 patients. A survey of primary and secondary treatment and of complications of treatment or fracture healing is presented in table 22.

Table 22. Complications of primary treatment.

Patient	Year	Fracture type	Primary treatment	Complications of primary treatment	Secondary treatment
nr 5	1918	II	traction	poor position	ivory pin
nr 6	1921	II	traction-POP	delayed union	ivory pin
nr 8	1927	II	traction	poor position	screw
nr 9	1928	III	screw	failed	traction-POP
nr 10	1928	II	traction	poor position	ivory pin
nr 11	1932	II	POP	delayed union	osteotomy
nr 13	1936	II	traction	poor position	nail
nr 18	1940	II	POP	delayed union	nail
nr 20	1941	II	nail	poor position	POP
nr 22	1945	II	nail	poor position	POP
nr 23	1947	II	POP	poor position	nail
nr 26	1948	II	operation	failed	POP
nr 39	1960	II	POP	poor position	nail
nr 72	1978	II	bedrest	dislocation	screw

A striking finding was that 12 of the 26 patients (46%) treated prior to 1950 developed a complication of treatment or fracture healing which necessitated a change to another form of treatment. After 1950 this was necessary in only 2 patients (4%).

VII.9.1 *Conservative treatment*

Conservative treatment can consist of bed rest, alone or in combination with traction, with a hip spica, or with a combination of traction and a hip spica. The primary treatment was conservative in 42 patients (57%). Complications necessitated a change to surgical treatment in 10 patients (24%). On the other hand, operative treatment was replaced by conservative treatment in 4 patients (13%). Finally 36 patients (49%) received conservative fracture treatment (table 23).

Table 23. Conservative treatment.

Conservative treatment	Primary conservative N_{42}	Conservative N_{36}
Bedrest	6(14%)	6(17%)
Bedrest - traction	20(48%)	16(44%)
POP	6(14%)	5(14%)
POP - traction	10(24%)	9(25%)

VII.9.2 *Operative treatment*

In Groningen, also, operative treatment has shown an evolution. In the early cases, various screws or an ivory pin were used. Subsequently the flanged nail was frequently used. Then came various other nails, vitallium screws and the AO cancellous bone screws.

As already mentioned, complications in the early cases not infrequently necessitated a change to conservative fracture treatment. Primary treatment was operative in 31 cases (42%); in 4 cases (13%), complications necessitated recourse to a conservative strategy. In 10 cases complications of conservative treatment necessitated secondary operative treatment, so that ultimately 37 patients (50%) received operative fracture treatment. A survey of the various methods used in operative fracture treatment is presented in table 24.

Table 24. Operative treatment.

Operative treatment	Primary operative N_{31}	Operative N_{37}
Ivory pin	– –	3(8%)
Screws	2(6%)	2(5%)
Nail	12(39%)	14(38%)
Knowles pins	4(13%)	4(11%)
Vitallium screws	4(13%)	4(11%)
AO cancellous bone screws	6(19%)	7(19%)
Miscellaneous	3(10%)	3(8%)

Although in the early years of this century an ivory pin was used in the operative treatment of fractures of the femoral neck in adults (Weijtlandt, 1923), there are no publications which recommend this form of treatment for femoral neck fractures in children and adolescents. The three patients treated by internal fixation of the femoral neck fracture with the aid of an ivory pin, had all received primary conservative treatment (table 22). Most of the proximal femoral fractures treated operatively in the early days were fixed with a flanged nail (38%), whereas today internal fixation is effected with screws (30%). Only a few fractures were fixed with Knowles pins (11%).

VII.9.3 *Method of reduction, time of reduction, and reduction achieved*

Optimal reduction is the primary prerequisite for fracture healing. Reduction of displaced fractures can be open or closed. Closed fracture reduction is effected without bringing the fracture into view. The time of reduction marks the interval since the occurrence of the fracture. Reduction achieved marks the situation attained after reduction.

As already mention, improved insights into the vascularization of the proximal femur, the aetiology of the proximal femoral fracture and the possible complications of fracture healing have highlighted the significance of the method of reduction, the time of reduction, and the reduction achieved. Most fractures were not treated according to current standards. This explains the small percentage of open reductions, the delays prior to reduction, and the small percentage of anatomical reductions achieved. Method of reduction, time of reduction and reduction achieved are surveyed in table 25.

Table 25a. Method of reduction.

Method	N_{71}
None	27(38%)
Closed	37(52%)
Closed / open	5(7%)
Open	2(3%)
Unknown	3 -

Table 25b. Time of reduction.

Time	N_{46}
0-24 hrs	13(28%)
24-28 hrs	1(2%)
48-72 hrs	6(13%)
4 days-1 wk	10(22%)
1 wk-1 month	11(24%)
> 1 month	5(11%)
Unknown	1 -

Table 25c. Reduction achieved.

Reduction	N_{57}
Anatomical	24(42%)
Almost anatomical	23(40%)
Non anatomical	10(18%)
Unknown	17 -

VII.9.4 *Systemic and local complications during treatment*

Apart from the previously described complications in the execution of conservative or operative treatment of proximal femoral fractures, systemic and/or local complications can occur during treatment. These systemic and/or local complications should be differentiated from complications of fracture healing.

None of the patients developed a systemic complication. Only 4 patients (5%) developed a local complication during treatment: superficial wound infection in 2 cases, wound infection with septic arthritis of the hip-joint in 1 case, and severe dorsal decubitus due to conservative treatment with a hip spica in 1 case.

VII.9.5 *Duration of hospitalization*

The duration of the hospital stay after a proximal femoral fracture in a child or adolescent depends on the patient's age, the type of fracture, and the treatment given. Other factors of influence are the presence or absence of complications of fracture healing, and possibility of transfer to a nursing home or rehabilitation centre. In any case the current hospital period cannot be compared with that of a few decades ago. In view of these facts, this study presents no data on the hospital period of the 74 patients involved.

VII.10 **Discussion**

Since the end of the 19th century the treatment of proximal femoral fractures in children and adolescents has evolved from conservative treatment to operative treatment. Improved knowledge concerning the aetiology of fractures, anatomical insights and knowledge concerning the aetiology of complications of fracture healing have led to improved methods of operative treatment, as described in detail in this chapter. This explains the diversity in methods of treatment, indications for operative or conservative treatment, and complications of primary treatment. The length of the period covered by the study also explains the differences in method of reduction, time of reduction, and reduction achieved.

Pertrochanteric fractures and, if necessary, undisplaced basal fractures can be treated conservatively with traction in abduction. Traumatic separation of the upper femoral epiphysis, transcervical fractures and displaced basal fractures should be treated operatively, preferably within 4-6 hours; this treatment involves decompression of the hip-joint after capsulotomy or puncture. After open or closed anatomical reduction of the fracture, internal fixation is effected with the aid of cancellous bone screws or Knowles pins. In the absence of complications of fracture healing, complete weightbearing can generally be resumed after 3-6 months, dependent on the patient's age, the degree of cooperation to be expected, and the type of fracture involved. Children and adolescents with a proximal femoral fracture require a prolonged follow-up with a view to possible short-term or long-term complications of fracture healing. The treatment of a complication of fracture healing is largely determined by individual factors, and also depends on the type of complication and the associated complaints as well as the complaints to be expected in the future.

CHAPTER VIII

METHODOLOGY OF FOLLOW-UP

VIII.1 Introduction

Of the 74 children and adolescents treated for a fracture of the proximal femur during the period 1909-1981 and discussed in this study, 61 (83%) are still alive. Nine patients (12%) have died, one death being an immediate result of the accident. The residence of 4 patients (5%) could not be traced. Of the 61 surviving patients, 58 (95%) were included in the follow-up study. Two were abroad at the time of this study and therefore not available for follow-up. One female patient refused to cooperate. The follow-up period ranged from 5 months to 69 years.

VIII.2 Method of locating patients

From the civil registry office of the patient's last known place of residence we obtained data on the patient's place of residence and address at the time of the follow-up or, if applicable, the date of death. In a few instances data were obtained via the national inspectorate of civil registry offices in The Hague. Unfortunately, the addresses of four patients could not be traced. To all surviving patients we addressed a letter stating the aims of the follow-up study and requesting the patients to present at the surgical outpatient clinic at a specified date and time. Patients who did not respond to this letter were again approached, by letter, by telephone or in person. Finally, only one female patient proved to be unwilling to cooperate.

VIII.3 Follow-up methods

The follow-up examination was performed by one investigator and consisted of three parts:

— history
— physical examination
— radiographic examination.

VIII.3.1 *History*

The history was taken by questioning the patient using a fixed protocol. The patient was asked to give his opinion on the final result of treatment, specifically in terms of hip-joint mobility, leg function and presence or absence of coxalgia. Questions were then asked about day-to-day activities and possible social consequences of the fracture at a later age.

VIII.3.2 *Physical examination*

This examination was likewise performed in accordance with a fixed protocol, the affected leg being compared with the unaffected leg (Kuijjer, 1971). Physical examination began with a study of the gait. The mobility of the hips was then examined, and leg length was measured between the superior anterior iliac spine and the lateral malleolus. The circumference of the thighs was measured 20 cm above the lateral articular space of the knee. Finally, the standing patient was examined for possible pelvic asymmetry and insufficiency of the abductor muscles. The latter was determined on the basis of Trendelenburg's sign.

VIII.3.3 *Radiographic examination*

Radiographic examination comprised three radiographs:
— an anteroposterior radiograph of the pelvis
— an anteroposterior radiograph of the pelvis in the Lauenstein projection
— an anteroposterior radiograph of both lower extremities.
In the radiographic examination the affected leg was always compared with the unaffected leg.

VIII.3.3.1 *Anteroposterior radiograph of the pelvis*

The anteroposterior radiograph of the pelvis was obtained with the patient supine on a Bucky table with both knees and feet in a neutral position. The ffd was 115 cm. The frame size was 35 x 43 cm.
The anteroposterior pelvic radiograph was studied with special reference to pre-existent traumatic and degenerative changes of the proximal femur and the hip-joint, noting the following points in particular:
— abnormal shape of the proximal femur
— avascular necrosis of the proximal femur
— premature epiphyseal fusion
— posttraumatic degenerative changes of the hip-joint
— the exact location of osteosynthesis material (if present).

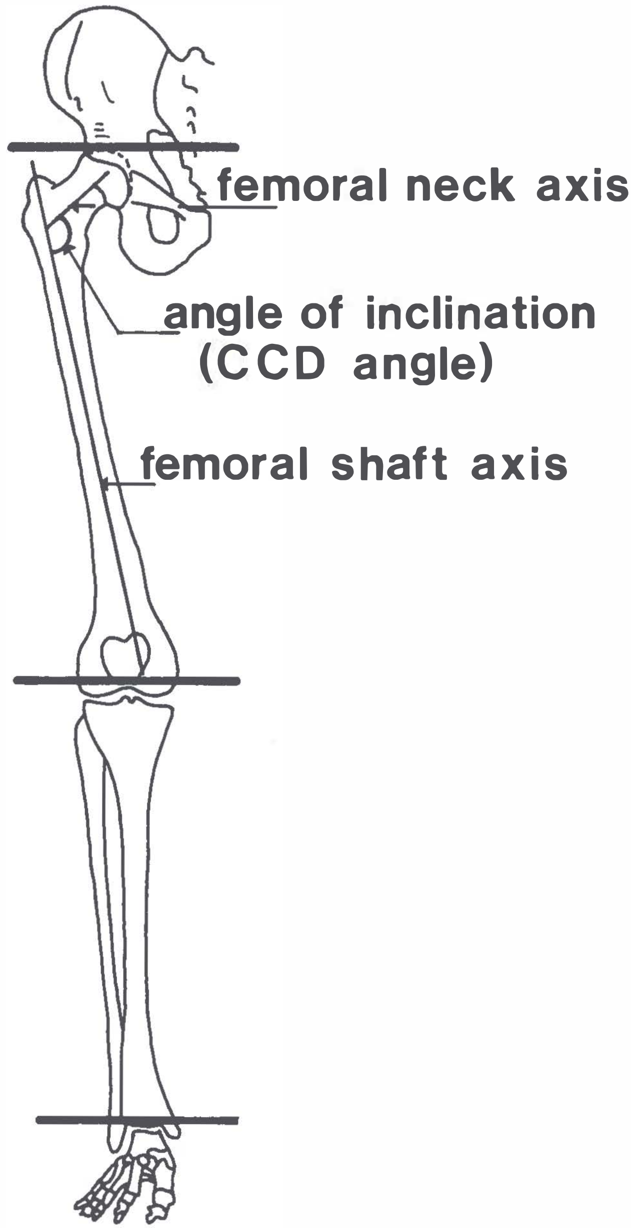


Fig. 6. Measurement of the CCD-angle from femoral neck axis and femoral shaft axis and measurement of the radiographic length of the thigh and the entire leg.

In addition, the CCD-angle of both proximal femurs was determined. This was calculated from the angle between the axis of the femoral neck and the axis of the femoral shaft (fig. 6; Keats et al., 1966).

VIII.3.3.2 *Anteroposterior radiograph of the pelvis in the Lauenstein projection*

The patient was placed supine on a Bucky table, both knees raised and spread, and the heels together. The ffd was 115 cm. The frame size was 35 x 43 cm.
The Lauenstein radiograph was again studied with special reference to pre-existent traumatic and degenerative changes of the proximal femur and the hip-joint, noting the following points in particular:
— abnormal shape of the proximal femur
— avascular necrosis of the proximal femur
— premature epiphyseal fusion
— posttraumatic degenerative changes of the hip-joint
— the exact location of osteosynthesis material (if present).

VIII.3.3.3 *Anteroposterior radiograph of both lower extremities*

This radiograph was likewise obtained with the patient supine, with the feet and knees in a neutral position. The ffd was 115 cm. The frame size was 30 x 100 cm.
The radiographic length of the thigh and of the entire leg was measured from this radiograph. For this purpose, three parallel lines were drawn: one along the femoral head, one along the intercondylar fossa of the femur, and one along the distal part of the tibia. The radiographic length of the thigh and of the entire leg was determined by determining the distances between these lines (fig. 6).

THE GRONINGEN STUDY

CHAPTER IX

THE RESULTS OF THE STUDY

IX.1 Introduction

This chapter presents a description of the results obtained in the follow-up study. The functional and anatomical results and the radiographic findings are first described. Next, the short-term and long-term social consequences of the injury are discussed. On this basis a review is presented of the ultimate therapeutic results.

IX.2 The patients examined

In 1981, 58 patients (78%), including 20 females (34%) and 38 males (66%) presented for a follow-up (table 26). The distribution of the fracture types in the children and adolescents is presented in table 27.

Table 26. Number of children and adolescents with a proximal femoral fracture per decade.

Period	Study group			Patients examined		
	N	♀	♂	N	♀	♂
1909-1920	5	2	3	2	1	1
1920-1930	5	1	4	–	–	–
1930-1940	8	3	5	6	2	4
1940-1950	8	2	6	6	2	4
1950-1960	11	2	9	10	2	8
1960-1970	18	8	10	15	6	9
1970-1981	19	7	12	19	7	12
1909-1981	74(100%)	25(34%)	49(66%)	58(78%)	20(34%)	38(66%)

Table 27. Distribution of the fracture types by sex and age group.

Fracture type	N_{58}	♀	♂	Children 0-11 yrs N	♀	♂	Adolescents 12-18 yrs N	♀	♂
Type I	–	–	–	–	–	–	–	–	–
Type II	34(59%)	11(32%)	23(68%)	5(15%)	5	–	29(85%)	6	23
Type III	13(22%)	3(23%)	10(77%)	3(23%)	2	1	10(77%)	1	9
Type IV	11(19%)	6(55%)	5(45%)	9(82%)	6	3	2(18%)	–	2
		20(34%)	38(56%)	17(29%)	13(76%)	4(24%)	41(71%)	7(17%)	34(83%)

IX.3 Functional results

Functional results were assessed on the basis of several criteria, namely: mobility of the hip-joint, gait and relation to complaints of pain in the vicinity of the hip-joint.

IX.3.1 *Mobility of the hip-joint*

As already described in chapter II, six movements or combinations of movements are possible in the hip-joint. Flexion, abduction and external rotation are of particular importance, while internal rotation, adduction and extension are less important. Flexion, abduction, adduction, internal rotation and external rotation of the hip-joint were examined in 58 patients lying supine in a neutral position. In two patients the movements of the affected hip could not be compared with those of the unaffected hip because the latter had been injured at a later age. In one patient there was an ankylosis of the involved hip. Movements of the affected hip could be compared with those of the unaffected hip in 56 patients (97%). By addition of all separate hip-joint movements, the total mobility of both hip-joints (expressed in degrees) was obtained. Table 28 shows the difference in total hip-joint mobility and in each separate hip-joint movement between the two hips in 56 patients. To obtain these data, the movement of the unaffected hip-joint was always subtracted from that of the affected hip-joint. Limitations were found in particular in internal rotation, external rotation and flexion. Abduction and adduction were hardly impaired.

Table 28. Difference in range of movement (°) between the affected and the unaffected hip-joint, for total mobility and each separate movement (* including ankylosis).

Difference movement (°)	Total mobility N_{56}	Seperate ranges of movement Flexion	Abduction	Adduction	External rotation	Internal rotation
Ankylosis	1					
– 145	1	–	–	–	–	–
– 110	2	–	–	–	–	–
– 70	1	–	–	–	–	–
– 60	1	1	–	–	–	–
– 50	1	1	–	–	–	–
– 45	2	–	–	–	–	–
– 40	1	1	–	1	–	–
– 35	–	1	–	–	–	–
– 30	3	–	1	1	1	4
– 25	–	1	–	–	2	1
– 20	4	4	1	–	5	4
– 15	7	–	1	–	–	3
– 10	8	1	3	13	6	14
– 5	4	5	2	3	4	2
0	14	37	46	35	26	14
+ 5	2	–	–	1	1	1
+ 10	4	3	1	1	8	10
+ 15	–	–	–	–	1	–
+ 20	–	–	–	–	1	1
+ 25	–	–	–	–	–	–
+ 30	–	–	–	–	–	1
Unknown	2	3*	3*	3*	3*	3*

The mobility of the hip-joint was unmistakably impaired in 10 patients (18%). Impairment was very serious (> 120° and ankylosis) in 2 patients (20%), serious (80-120°) in 2 patients (20%), moderate (60-80°) in 2 patients (20%) and slight (40-60°) in the remaining 4 patients (40%). These data are presented in table 29.

The 10 patients were evenly distributed over the decades. Impairment of hip-joint movement occurred in 2 children (12%) and 8 adolescents (21%), i.e. in 3 females (15%) and 7 males (19%). A transcervical fracture was involved in 7 cases (22%) and a basal fracture in 3 cases (23%). No impairment of hip mobility was observed after pertrochanteric fractures.
Of the patients who received primary conservative treatment, 6 (21%) showed impaired hip-joint movement. The same applied to 4 patients

Table 29. Impairment (°) of the total mobility of the hip-joint and of each separate movement (°).

Impairment	N_{10}	Total mobility (°)	Flexion	Abduction	Adduction	External rotation	Internal rotation
			Separate ranges of movement				
Very serious	2	ankylosis					
		- 145	- 60	- 5	- 30	- 30	- 20
Serious	2	- 110	- 40	0	- 40	0	- 30
		- 110	- 35	- 20	- 10	- 20	- 25
Moderate	2	- 70	- 25	0	- 10	- 25	- 10
		- 60	- 50	0	- 10	0	0
Slight	4	- 50	- 20	- 30	+10	- 5	- 5
		- 45	- 5	0	- 10	- 20	- 10
		- 45	- 10	- 5	- 10	+10	- 30
		- 40	+10	- 10	- 10	- 20	- 10

(15%) who received primary operative treatment. The impairment of movement in the 6 patients who received primary conservatieve treatment was more marked than that in the 4 patients who received primary operative treatment (table 30).

Table 30. Impairment hip-joint mobility according to primary treatment.

Impairment	Primary treatment: Conservative N_{29}	Operative N_{27}
None	23 (79%)	23(85%)
Slight	1 (3%)	3(11%)
Moderate	2 (7%)	-(-)
Serious	2 (7%)	-(-)
Very serious	1 (3%)	1(4%)
Unknown	1	1

Of the 14 patients in whom a complication developed in the primary treatment of the fracture (table 22), only 6 (43%) were available for the follow-up study. Hip movement was impaired in 3 of these 6 patients (50%); the impairment was serious in 1 and moderate in the other 2 patients.
Merle d'Aubigné (1949) and Harris (1962, 1982) each introduced a classification of hip-joint mobility. Using the classification of Merle d'Aubigné, hip-joint mobility was decreased in 10 patients (18%); using the Harris

classification it was found decreased in 13 patients (23%). However, if the mobility of the unaffected hip was included by comparison, then hip-joint movement was impaired in 9 patients (16%) according to the Merle d'Aubigné classification, and in 11 patients (20%) according to that of Harris.

Ratliff (1962) classified hip-joint mobility after proximal femoral fractures in children and adolescents into only three categories. Applying his classification, we found impaired hip-joint mobility in 9 patients (16%).

Dependent on the classification used and possible correction of mobility by comparison with that of the unaffected hip-joint, 9-13 patients (16% - 23%) showed impaired mobility of the affected hip. Table 31 presents a survey of total hip-joint mobility in these 58 patients as classified according to Merle d'Aubigné (1949), Harris (1982) and Ratliff (1962).

Table 31. Impairment (°) of hip-joint mobility with and without correction (*), according to the classification of Merle d'Aubigné, Harris and Ratliff.

Merle d'Aubigné	N_{56}	Harris	N_{56}
ankylosis	1 (1) (2%)	0- 30	1 (1) (2%)
0- 70	1 (1) (2%)	40- 60	- - -
70-140	2 (1) (3%)	60-100	1 (1) (2%)
140-200	6 (6) (11%)	100-160	4 (1) (7%)
200-300	46 (47) (82%)	160-210	7 (8) (12%)
		210-260	43 (45) (77%)
unknown	2 (2)	unknown	2 (2)
impairment	10 (9*)(18%)	impairment	13 (11*)(23%)

Ratliff	N_{56}	Hoekstra	N_{56}
less than 50%	2 (4%)	very serious	2 (4%)
greater than 50%	7 (12%)	serious	2 (4%)
full or terminal restriction	47 (84%)	moderate	2 (4%)
		mild	4 (7%)
		normal	46 (82%)
unknown	2	unknown	2
impairment	9 (16%)	impairment	10 (18%)

When the history was taken, 17 patients (30%) indicated reduced or disturbed hip function. In only 7 patients (41%) did examination of the hip-joint reveal impaired mobility.

IX.3.2 *Gait*

Disturbances in gait (including reduced walking distance) are caused by pain in the hip-joint due to degenerative changes, changes in the position of the proximal femur, and/or a difference in leg length.

Only 43 patients showed a normal gait with an unrestricted walking distance (78%), while 9 patients (16%) showed a slightly disturbed gait without restriction of the walking distance. Only 3 patients (6%) showed a severely disturbed gait, had to use a cane, or had a walking distance of only 200-500 metres. In 3 patients the gait was disturbed for other reasons. Table 32 presents data on the ability to walk according to the classification of Merle d'Aubigné (1949).

Table 32. Ability to walk according to the classification of Merle d'Aubigné.

Ability to Walk (Merle d'Aubigné)	N_{55}
None	– –
Only with crutches	– –
Only with canes	– –
With one cane, less than one hour; very difficult without a cane	2 (4%)
A long time with a cane; short time without cane and with limp	1 (2%)
Without cane but with slight limp	9 (16%)
Normal	43 (78%)
Limited for other reason	3 –

A disturbed gait, alone or in combination with diminished walking distance, develop in 12 patients (22%): 3 children (18%) and 9 adolescents (24%), 7 females (35%) and 5 males (14%), 9 patients with a transcervical fracture (29%), 2 patients with a basal fracture (15%) and 1 patient with a pertrochanteric fracture (9%). Primary treatment had been conservative in 7 (24%) of these 12 patients, and operative in 5 (19%).

Of the 6 patients studied after a complication in primary treatment, 4 (67%) had a disturbed gait and/or walking distance. Of the 10 patients with impaired hip-joint mobility, 8 (80%) had a disturbed gait and/or walking distance.

IX.3.3 *Complaints of pain in the hip*

Complaints of pain initially occurred only after prolonged movement, subsequently also after brief movement, and finally even at rest. Progression of pain symptoms is as a rule associated with a disturbed gait and/or walking distance, and impaired hip mobility. Pain symptoms in the hip after proximal femoral fractures have been classified, per sé or in relation to the gait, by Merle d'Aubigné (1949) and by Ratliff (1962). These data are presented in table 33.

Table 33. Classification of hip pain according to Merle d'Aubigné and Ratliff.

Pain (Merle d'Aubigné)	N_{58}	Pain (Ratliff)	N_{58}
Pain is intense and permanent	– –	Severe	– –
Pain is severe even at night	– –	Occasional	8 (14%)
Pain is severe when walking; prevents any activity	– –	None or "ignores"	50 (86%)
Pain is tolerable with limited activity	– –		
Pain is mild when walking; it disappears with rest	2 (4%)		
Pain is mild and inconstant; normal activity	6 (10%)		
No pain	50 (86%)		

Complaints of pain in the hip were present in 8 patients (14%): 2 children (12%) and 6 adolescents (15%), 4 females (20%) and 4 males (11%). Primary treatment had been conservative in 5 (17%) of these 8 patients, and operative in 3 (11%). These 8 patients included 5 with a transcervical fracture (15%), 2 with a basal fracture (15%) and 1 with a pertrochanteric fracture (9%).

The pain in the hip was associated with a disturbed gait and/or walking distance in 6 patients (75%) and with impaired hip-joint mobility in only 3 patients (38%). None of the 6 patients studied after a complication in primary treatment of the proximal femoral fracture complained of pain in the hip.

IX.3.4 *Discussion*

After a proximal femoral fracture, impaired hip-joint mobility developed in 10 patients (18%), a disturbed gait and/or walking distance in 12 patients (22%), and complaints of pain in the hip in 8 (14%).

Impaired hip-joint mobility was more frequently seen after a transcervical than after a basal fracture. No impairment was observed after a pertrochanteric fracture. A disturbed gait and/or walking distance was more frequently seen after a transcervical than after a basal fracture, and after a pertrochanteric fracture in only 1 patient. Pain in the hip was as frequent after transcervical as after basal fracture, and occurred in only 1 patient after a pertrochanteric fracture.

Impaired hip mobility was associated with a disturbed gait in 8 patients (80%) and with pain in the hip in only 3 patients (30%).

Impaired hip-joint mobility, disturbed gait and/or walking distance and pain in the hip were more frequently found after primary conservative than after primary operative fracture treatment, and more often in adolescents than in children. The latter is explained by the larger percentage of type IV (pertrochanteric) fractures in the group of children.

IX.4 **Anatomical results**

Following both primary conservative and primary operative treatment of proximal femoral fractures, changes in the position of the proximal femur may develop; and sometimes, in an immature proximal femur, longitudinal growth may be impaired. In order to investigate this, the following points were noted:

— Radiographic leg length.
— Changes in the position of the proximal femur.
— Pelvic asymmetry, Trendelenburg's sign, and the circumference of the quadriceps femoris muscle.

IX.4.1 *Radiographic leg length measurement*

In 46 patients (79%) there were no other changes in the two lower extremities, and in these cases radiographic measurement of the length of the thigh and of the entire leg was performed, with a comparative measurement of the contralateral extremity (table 34).

A difference in thigh length was found in 28 patients (61%), while 35 patients (76%) showed a difference in leg length. The difference in thigh length averaged - 4.2 mm, and that in leg length averaged - 6.1 mm.

A difference in leg length of up to 1-1½ cm was considered to be within physiological limits (Moscher, 1977; Sybrandy, 1981). In these terms a difference in leg length existed in 12 patients (26%): 4 children (31%) and 8 adolescents (24%), 4 females (25%) and 8 males (27%). Shortening occurred in 8 patients (17%), and lengthening in 4 (9%).

Table 34. Difference in thigh length and leg length.

Difference in length	Thigh length N_{46}	Leg length N_{46}
	Shortening 5(11%)	Shortening 8(17%)
- <-30 mm	2	2
- 20-30 mm	2	5
- 15-20 mm	1	1
	Normal 41(89%)	Normal 34(74%)
- 10-15 mm	7	9
- 5-10 mm	9	8
none	18	11
+ 5-10 mm	4	4
+ 10-15 mm	3	2
	Lengthening -	Lengthening 4(9%)
+ 15-20 mm	-	3
+ 20-30 mm	-	1
+ > 30 mm	-	-

Leg shortening occurred in 1 child (8%) and 7 adolescents (21%), 2 females (13%) and 6 males (20%), and ranged from 1.5 cm to 7.2 cm. The shortening occurred after a transcervical fracture in 8 patients (28%). Primary treatment had been conservative in 5 (22%) and operative in 3 patients (13%).

Leg lengthening occurred in 4 patients: 3 children (23%) and 1 adolescent (3%), 2 females (13%) and 2 males (7%). It occurred after a transcervical fracture in 2 patients (7%) and after a pertrochanteric fracture in 2 children (29%). Primary treatment had been conservative in 1 case (4%) and operative in 3 cases (13%).

IX.4.2 *Changes in the position of the proximal femur*

The anatomy of the proximal femur and the changes in the CCD-angle and the AV-angle during proximal femoral growth and at a later age have been described in section 2 of chapter II. Changes in the CCD-angle and in the AV-angle can occur also after proximal femoral fractures, and become manifest mainly in posttraumatic coxa vara or valga, as described in section 4 of chapter IV.

In children, the position of the proximal femur can be simply determined via the actual CCD-angle and AV-angle with the aid of an anteroposterior radiograph of the pelvis and a Rippstein projection (Rippstein, 1955; Müller, 1979). In this follow-up study, however, this method was not feasible because the age at follow-up ranged from 6 years to 77 years. For this reason we determined only the CCD-angle of the proximal femur according to Keats, as described in subsection 3.3.1 of chapter VIII (Keats et al., 1966).

The CCD-angle was determined in 56 patients (97%) available for this study. Posttraumatic coxa vara was diagnosed when the CCD-angle was 120° or less and differed by more than 15° from the CCD-angle of the unaffected proximal femur. Posttraumatic coxa valga was diagnosed when the CCD-angle was 150° or more and differed by more than 15° from the CCD-angle of the unaffected proximal femur.

Posttraumatic coxa vara developed in 3 patients (5%): 2 children (12%) and 1 adolescent (2%), 2 patients with a type II (transcervical) fracture (6%) and 1 patient with a type IV (pertrochanteric) fracture (9%), in 2 cases after primary conservative (7%) and in 1 case after primary operative treatment (4%). Impaired hip-joint mobility was present in 2 of the 3 patients, disturbed gait and/or walking distance in all 3, pain in the hip in 2 patients, a difference in leg length in 1, and a positive Trendelenburg sign in none (table 35).

Table 35. Changes in the position of the proximal femur and associated complaints.

Age years	Varus/ valgus	Fracture type	Treat- ment	Hip-joint mobility	Gait	Pain	Difference leg-length	Tren- delenburg sign
	Varus							
16	111°	II	C	+	+	+	+	-
5	115°	II	O	+	+	-	-	-
10	115°	IV	C	-	+	+	-	-
	Valgus							
10	150°	II	C	+	+	+	+	+
18	150°	II	O	-	-	-	+	-
18	152°	II	C	-	-	-	-	-
13	160°	II	C	+	+	-	+	-
9	165°	II	O	-	-	-	+	-

(C = conservative and O = operative; + = abnormal and - = normal)

Posttraumatic coxa valga developed in 5 patients (9%): 2 children (12%) and 3 adolescents (7%). In all 5 cases it developed after a transcervical fracture (15%), after primary conservative treatment in 3 (10%) and after primary operative treatment in 2 cases (7%). In 4 patients (80%) it was associated with other complications, mainly impaired hip-joint mobility, disturbed gait and/or walking distance, and a difference in leg length (table 35).

Changes in the position of the proximal femur therefore occurred in a total of 8 patients (14%): 4 children (24%) and 4 adolescents (10%). They occurred after a transcervical fracture in 7 patients (21%) and after a pertrochanteric fracture in 1 (9%), after primary conservative treatment in 5 cases (17%) and after primary operative treatment in 3 (11%). The principal associated complications were impaired hip-joint mobility (50%), a disturbed gait and/or walking distance (63%) and a difference in leg length (63%) (table 35).

IX.4.3 *Pelvic asymmetry, Trendelenburg's sign and the circumference of the femoral quadriceps muscle*

A difference in femoral length can result from changes in the position and/or impairment of the growth of the proximal femur, giving rise to pelvic asymmetry and sometimes even leading to insufficiency of the abductors of the hip due to elevation of the trochanter. This is expressed by a positive Trendelenburg sign. Impaired leg function can lead to a reduction of the circumference of the femoral quadriceps muscle in relation to that on the contralateral side. Pelvic asymmetry, Trendelenburg's sign and the circumference of the quadriceps muscle were compared in 46 patients (79%) without other abnormalities of the lower extremities.

Pelvic asymmetry was present in 20 patients (43%): 6 children (45%) and 14 adolescents (42%), 6 females (38%) and 14 males (47%). The asymmetry was to the disadvantage of the homolateral side in 16 cases (34%), and to the disadvantage of the contralateral side in 4 (9%). It occurred after primary conservative treatment in 9 cases (39%) and after primary operative treatment in 11 (44%), after a transcervical fracture in 13 patients (45%), after a basal fracture in 6 (60%) and after a pertrochanteric fracture in 1 patient (7%). The pertrochanteric fracture was followed by pelvic assymetry to the disadvantage of the contralateral side. Fracture types and methods of treatment were evenly distributed. Impaired hip-joint mobility was associated with pelvic asymmetry in 8 patients (80%).

A positive Trendelenburg sign indicating insufficiency of the abductors of the hip due to an elevated trochanter and/or coxa vara was present in 3 patients (7%): 1 child and 2 adolescents. In all three cases it was observed on the homolateral side and after a transcervical fracture (10%). Primary treatment had been conservative in all 3 cases (13%). In only 1 case was the positive Trendelenburg sign associated with pelvic asymmetry to the disadvantage of the homolateral side. In 2 patients (20%), impaired hip-joint mobility was associated with insufficiency of the hip abductors.

The homolateral quadriceps femoris muscle was found to be reduced by more than 1 cm in 16 patients (35%): 2 children (15%) and 14 adolescents (42%), 4 females (25%) and 12 males (40%). The patients who received primary conservative treatment included 10 (43%) with atrophy of the quadriceps muscle, and the patients who received primary operative treatment included 6 patients (24%) with this atrophy. The homolateral quadriceps femoris muscle was increased in circumference by more than 1 cm in 2 patients (4%) (table 36).

Table 36. Difference in circumference and state of quadriceps femoris muscle.

Difference circumference	N_{46}	State of quadriceps femoris muscle	
– 5 cm	1		
– 4 cm	4	Atrophy	35%
– 3 cm	5		
– 2 cm	6		
– 1 cm	10		
0 cm	13	Normal	61%
+ 1 cm	5		
+ 2 cm	2		
+ 3 cm	–	Hypertrophy	4%
+ 4 cm	–		
+ 5 cm	–		

Atrophy of the quadriceps femoris muscle occurred in 14 patients with a type II (transcervical) fracture (48%) and in 2 with a type III (basal) fracture (20%). The atrophy was associated with pelvic asymmetry in 8 patients (50%). A positive Trendelenburg sign was associated with atrophy of the quadriceps femoris muscle in all patients. Of the 5 patients with atrophy of the quadriceps femoris muscle of 4 cm or more, 4 (80%) showed moderate to very serious impairment of hip-joint mobility. A slight impairment of hip-joint mobility occasionally gave rise to some reduction of the circumference of the quadriceps femoris muscle.

IX.4.4 *Discussion*

After a proximal femoral fracture in a child or adolescent, a difference in leg length was observed in 12 patients (26%). Shortening was present in 8 patients (17%), in all cases after a transcervical fracture and more often after primary conservative than after primary operative treatment; the shortening ranged from 1.5 cm to 7.2 cm. Ratliff (1978) found leg shortening in 30% of children and adolescents with proximal femoral fractures; the shortening ranged from 1.5 cm to 13 cm. The leg was found to be lengthened in 4 patients (9%): 2 with a transcervical and 2 with a pertrochanteric fracture.

Changes in the position of the proximal femur developed in 8 patients (14%): coxa vara in 3 (5%) and coxa valga in 5 patients (9%). It occurred after a transcervical fracture in 7 patients and after a pertrochanteric fracture in 1 patient, and more often after primary conservative than after primary operative treatment. The changes in the position of the proximal femur mainly gave rise to impaired hip-joint mobility, a disturbed gait and/or walking distance, and a difference in leg length.

Changes in the position of the proximal femur and/or a difference in leg length can cause pelvic asymmetry, insufficiency of the hip abductors, and atrophy of the quadriceps femoris muscle. Pelvic asymmetry developed in 20 patients (43%): to the disadvantage of the homolateral side in 16 (34%) and to the disadvantage of the contralateral side in 4 (9%). It was found as often after primary conservative as after primary operative treatment, and slightly more often after a basal than after a transcervical fracture. One pertrochanteric fracture gave rise to pelvic asymmetry to the disadvantage of the contralateral side. Only 3 patients (7%) developed a positive Trendelenburg sign. Atrophy of the quadriceps femoris muscle was present in 16 patients (35%), more often after primary conservative than after primary operative treatment and more often after a transcervical than after a basal fracture. Atrophy in excess of 4 cm was associated with serious to very serious impairment of hip-joint mobility.

IX.5 Radiography findings

IX.5.1 *Radiographic features of the proximal femur*

Radiographic features of the proximal femur were studied in 57 patients (98%) and found to be abnormal in 23 (40%). The abnormalities were slight in 13 patients (23%) and serious in 10 (17%).

Abnormal radiographic features of the proximal femur were found more often in adolescents (45%) than in children (30%), and as often in females (40%) as in males (41%). The difference between children and adolescents is caused by the large percentage of pertrochanteric fractures in the group of children. Changes in the radiographic features of the proximal femur occurred after a road traffic accident in 10 patients (36%) and after a fall from a great height in 7 (41%). After a fall on the hip while walking, all patients developed changes in the radiographic features of the proximal femur. Pre-existent changes in the proximal femur were not demonstrable in any of these patients. After a fall on the hip while skating, fighting or otherwise, a change in the radiographic features of the proximal femur developed in only 2 patients (24%). The clinical data and the radiographic features of the proximal femur are surveyed in table 37.

A change in the radiographic features of the proximal femur was observed after a type II (transcervical) fracture in 19 patients (57%), after a type III (basal) fracture in 3 patients (23%), and after a pertrochanteric fracture (type IV) in 1 patient (9%). Changes in the radiographic features of the proximal femur were observed more often in fractures with epiphyseal fusion (46%) than in those without epiphyseal fusion (33%), but in the latter group the changes were more pronounced. Changes were observed more often in fractures with complete displacement (50%) than in those with no or only slight displacement (22%). The transcervical fractures were classified according to Garden and according to Pauwels. Changes in the radiographic features of the proximal femur were found in 19 patients with a transcervical fracture (57%), and most often in transcervical fractures of Garden's type IV (69%) and of Pauwels' types II and III (60%).

Treatment had been delayed for more than 24 hours in 20 patients (35%). In 9 of these (45%), a change in the radiographic features of the proximal femur occurred. Treatment had not been delayed in 37 patients (65%); changes in the radiographic features of the proximal femur nevertheless occurred in 14 of these patients (38%).

Table 37. Clinical data and radiographic features of the proximal femur.

Clinical data	N_{57}	Radiographic abnormalities of the proximal femur None 34(60%)	Slight 13(23%)	Serious 10(17%)
Age				
child	17(30%)	12(70%)	2(12%)	3(18%)
adolescent	40(70%)	22(55%)	11(28%)	7(17%)
Sex				
female	20(35%)	12(60%)	2(10%)	6(30%)
male	37(65%)	22(59%)	11(30%)	4(11%)
Cause of accident				
road traffic accident	28(49%)	18(64%)	5(18%)	5(18%)
fall from a height	17(30%)	10(59%)	4(23%)	3(18%)
other type of fall	4(7%)	–	4(100%)	–
miscellaneous	8(14%)	6(76%)	–	2(24%)
Fracture type				
Type I	–	–	–	–
Type II	33(58%)	14(43%)	11(33%)	8(24%)
Type III	13(23%)	10(77%)	2(15%)	1(8%)
Type IV	11(19%)	10(91%)	–	1(9%)
Epiphysis				
open	39(68%)	26(67%)	6(15%)	7(18%)
closed	13(23%)	7(54%)	6(46%)	–
unknown	5(9%)	1(20%)	1(20%)	3(60%)
Displacement				
none	9(16%)	7(78%)	2(22%)	–
slight	10(17%)	8(80%)	1(10%)	1(10%)
complete	26(46%)	13(50%)	9(35%)	4(15%)
unknown	12(21%)	6(50%)	1(8%)	5(42%)
Displacement				
absent	9(16%)	7(78%)	2(22%)	–
present	36(63%)	21(58%)	10(28%)	5(14%)
unknown	12(21%)	6(50%)	1(8%)	5(42%)
Fracture type II displacement	N_{33}	14(43%)	11(33%)	8(24%)
Garden I	6(18%)	4(67%)	2(33%)	–
Garden II	5(15%)	4(80%)	–	1(20%)
Garden III	2(6%)	1(50%)	1(50%)	–
Garden IV	16(49%)	5(31%)	7(44%)	4(25%)
unknown	4(12%)	–	1(25%)	3(75%)
Fracture type II displacement	N_{33}	14(43%)	11(33%)	8(24%)
Pauwels I	4(12%)	4(100%)	–	–
Pauwels II	23(70%)	10(44%)	9(39%)	4(17%)
Pauwels III	2(6%)	–	1(50%)	1(50%)
unknown	4(12%)	–	1(25%)	3(75%)

Table 38. Treatment and radiographic features of the proximal femur.

Treatment	N_{57}	Radiographic abnormalities of the proximal femur None 34(60%)	Slight 13(23%)	Serious 10(17%)
Delay treatment				
0-24 hrs	37(65%)	23(62%)	9(24%)	5(14%)
>24 hrs	20(35%)	11(55%)	4(20%)	5(25%)
Primary treatment				
conservative	30(53%)	22(73%)	2(7%)	6(20%)
operative	27(47%)	12(44%)	11(41%)	4(15%)
Treatment				
conservative	26(45%)	22(84%)	1(4%)	3(12%)
conservative/operative	4(7%)	–	1(25%)	3(75%)
operative	26(45%)	12(46%)	11(42%)	3(12%)
operative/conservative	1(2%)	–	–	1(100%)
Reduction				
none	20(35%)	17(85%)	1(5%)	2(10%)
closed	30(53%)	13(43%)	12(40%)	5(17%)
open	5(9%)	3(60%)	–	2(40%)
unknown	2(3%)	1(50%)	–	1(50%)
Reduction achieved				
anatomical	23(40%)	15(66%)	4(17%)	4(17%)
nonanatomical	25(44%)	15(60%)	8(32%)	2(8%)
unknown	9(16%)	4(44%)	1(12%)	4(44%)
Delay operation	N_{27}	12(44%)	11(41%)	4(15%)
0-24 hrs	10(37%)	6(60%)	3(30%)	1(10%)
>24 hrs	17(63%)	6(35%)	8(47%)	3(18%)
Fixation	N_{27}	12(44%)	11(41%)	4(15%)
screws	10(37%)	5(50%)	3(30%)	2(20%)
Knowles pins	4(15%)	1(25%)	2(50%)	1(25%)
nail	12(44%)	5(42%)	6(50%)	1(8%)
miscellaneous	1(4%)	1(100%)	–	–
Fixation	N_{27}	12(44%)	11(41%)	4(15%)
transepiphyseal	17(63%)	7(41%)	8(47%)	2(12%)
nonepiphyseal	9(33%)	4(45%)	3(33%)	2(22%)
unknown	1(4%)	1(100%)	–	–

Primary treatment had been conservative in 30 patients (53%) and operativ in 27 (47%). A change in the radiographic features of the proximal femur occurred in 8 of the former 30 patients (27%) and in 15 of the latter 27 (56%). The radiographic changes were more serious after primary conservative than after primary operative treatment. In all cases a change in primary treatment was associated with changes in the radiographic features of the proximal femur.

No fracture reduction was performed in 20 patients (35%). Closed reduction was performed in 30 patients (53%), while in 4 patients (7%) initial closed reduction was followed by open reduction. Primary open reduction was performed in 1 patient (2%). For 2 patients there was no record on whether reduction had or had not been performed. The 20 cases in which no reduction was performed included 3 (15%) in which changes in the radiographic features of the proximal femur developed. Of the 35 patients in whom reduction was performed, 19 (54%) developed changes in the radiographic features of the proximal femur.

The reduction achieved was anatomical in 23 patients (40%) and non-anatomical in 25 (44%). A change in the radiographic features of the proximal femur occurred virtually as often in the former (34%) as in the latter group (40%).

An operation was performed within 24 hours in 10 patients (37%); 3 of them (30%) developed slight changes in the radiographic features of the proximal femur, while 1 (10%) development pronounced radiographic changes. After a delay in operation of more than 24 hours, 11 patients (65%) later developed radiographic changes. Of the 27 patients treated by internal fixation of the fracture, 12 (44%) showed normal radiographic features of the proximal femur, 11 (41%) showed slight radiographic changes, and 4 (15%) showed pronounced changes. The type of osteosynthesis material used, and whether fixation was transepiphyseal or not, produced almost no differences in the radiographic features of the proximal femur.

A survey of treatments given and of the radiographic aspects of the proximal femur is presented in table 38.

IX.5.2 *Avascular necrosis of the proximal femur*

In our study, avascular necrosis of the proximal femur were classified according to Ratliff (1962), as already described in subsection 2.4 of chapter IV. Avascular necrosis of the proximal femur developed in 10 patients (17%); it was of type I according to Ratliff in 8 (14%) and of type III in 2 patients (3%). Ratliff type II avascular necrosis was not observed (fig. 7).

Avascular necrosis of the proximal femur occurred in 2 children (12%) and 8 adolescents (20%), i.e. in 5 females (25%) and 5 males (18%). In all these cases the avascular necrosis developed after a transcervical fracture.

In the group of 34 patients with a transcervical fracture 10 patients (29%) developed avascular necrosis: 2 children (40%) and 8 adolescents (28%), i.e.

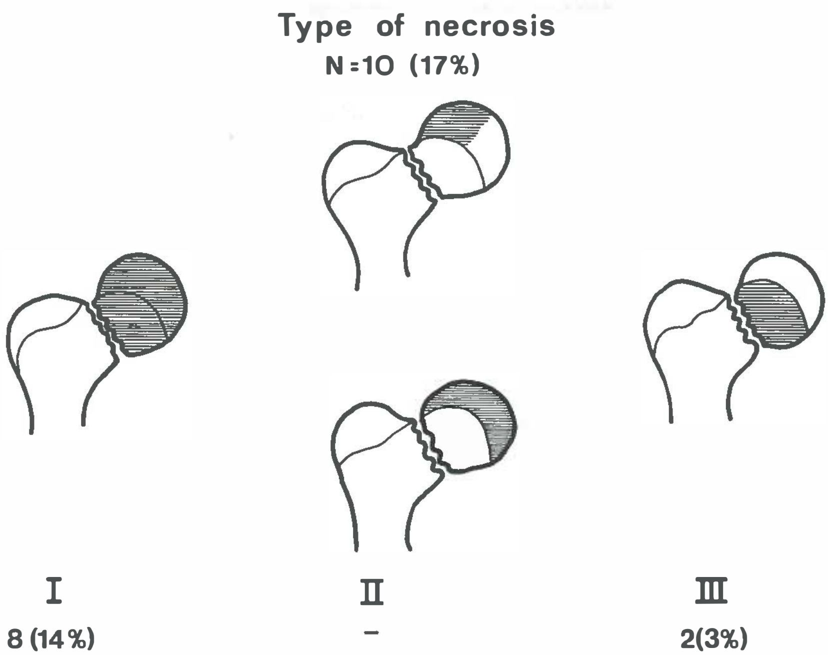


Fig. 7. The three radiological types of avascular necrosis of the femoral head and neck and number of cases.

in 5 females (45%) and 5 males (22%). Avascular necrosis developed in 5 (25%) of the 20 patients treated immediately, and in 5 (36%) of the 14 patients treated after a delay of more than 24 hours. Avascular necrosis developed in 5 (25%) of the 20 patients who received primary operative treatment. It developed in 1 (20%) of the 5 patients so treated without delay, and in 4 (27%) of the 15 patients whose operation had been delayed. In the group who received primary conservative treatment, 5 (36%) of the 14 patients developed avascular necrosis. In 3 patients, complications of primary conservative treatment necessitated secondary operative treatment. Avascular necrosis of the proximal femur developed in all these cases. In 2 patients, complications of primary operative treatment necessitated recourse to secondary conservative treatment; 1 of these patients developed avascular necrosis of the proximal femur. A complication during primary treatment was followed by avascular necrosis of the proximal femur in a total of 4 patients (80%). Primary treatment consisted of internal fixation in 20 patients with a transcervical fracture (59%). Avascular necrosis developed in 2 cases after screw fixation (40%), in 1 case after fixation with a Knowles pin (50%) and in 2 cases after nail fixation (17%).

Table 39. Transcervical fractures (Type II) and avascular necrosis.

Clinical data and treatment transcervical fractures (Type II)	N_{34}	Avascular necrosis Present 10 (29%)	Avascular necrosis Absent 24 (71%)
Age			
child	5 (15%)	2 (40%)	3 (60%)
adolescent	29 (85%)	8 (28%)	21 (72%)
Epiphysis			
open	20 (59%)	6 (30%)	14 (70%)
closed	10 (29%)	1 (10%)	9 (90%)
unknown	4 (12%)	3 (75%)	1 (25%)
Displacement			
absent	6 (17%)	1 (17%)	5 (83%)
present	24 (71%)	6 (25%)	18 (75%)
unknown	4 (12%)	3 (75%)	1 (25%)
Garden			
type I	6 (17%)	1 (17%)	5 (83%)
type II	5 (15%)	1 (20%)	4 (80%)
type III	2 (6%)	-	2 (100%)
type IV	17 (50%)	5 (29%)	12 (71%)
unknown	4 (12%)	3 (75%)	1 (25%)
Pauwels			
type I	4 (12%)	-	4 (100%)
type II	24 (70%)	5 (21%)	19 (79%)
type III	2 (6%)	2 (100%)	-
unknown	4 (12%)	3 (75%)	1 (25%)
Reduction achieved			
anatomical	14 (41%)	3 (21%)	11 (79%)
nonanatomical	16 (47%)	4 (25%)	12 (75%)
unknown	4 (12%)	3 (75%)	1 (25%)
Primary treatment			
operative	20 (59%)	5 (25%)	15 (75%)
conservative	14 (41%)	5 (36%)	9 (64%)
Delay treatment			
0-24 hrs	20 (59%)	5 (25%)	15 (75%)
>24 hrs	14 (41%)	5 (36%)	9 (64%)
Delay operation			
0-24 hrs	5 (25%)	1 (20%)	4 (80%)
>24 hrs	15 (75%)	4 (27%)	11 (73%)
Fixation			
screws	5 (25%)	2 (40%)	3 (60%)
Knowles pins	2 (10%)	1 (50%)	1 (50%)
nail	12 (60%)	2 (17%)	11 (83%)
miscellaneous	1 (5%)	-	1 (100%)
Complications of primary treatment			
operative	2 (40%)	1 (50%)	1 (50%)
conservative	3 (60%)	3 (100%)	-

Accident radiographs were available for 30 of the 34 patients with a transcervical fracture. Avascular necrosis of the proximal femur occurred in 7 cases in this group. It also occurred in 3 of the 4 patients whose accident radiographs were not available for study. The following is an analysis of the data on 30 patients with a transcervical fracture, 7 of whom developed avascular necrosis of the proximal femur.
Avascular necrosis occurred in 6 patients (30%) before epiphyseal fusion, and in 1 case (10%) after fusion. It occurred in 1 patient with an undisplaced fracture (17%) and in 6 with a displaced fracture (25%). It occurred in 1 patient with a Garden type I fracture (17%), 1 with a Garden type II fracture (20%) and 5 patients with a Garden type IV fracture (29%). No patient with a Pauwels type I fracture showed avascular necrosis, but 5 patients with a Pauwels type II fracture (21%) and both patients with a Pauwels type III fracture (100%) did. Anatomical reduction was achieved in 14 patients, 3 of whom (21%) subsequently developed avascular necrosis. Avascular necrosis occurred in 4 (25%) of the 16 cases without anatomical reduction. A survey of the above data is presented in table 39.

IX.5.3 *Premature epiphyseal fusion*

The epiphyseal plate of the femoral head was still open at the time of the accident in 39 patients (67%), while in 14 (24%) it had already fused; in 5 cases (9%) epiphyseal fusion or non-fusion could not be traced. Premature epiphyseal fusion occurred in 5 patients (13%).
Premature epiphyseal fusion occurred in 3 (16%) of the 20 patients (45%) who received primary operative treatment; for 1 patient this was unknown (table 40). The osteosynthesis material traversed the epiphyseal plate in 9 patients (47%), and in 1 patient (11%) this prompted premature epiphyseal fusion. In 10 cases the osteosynthesis material did not traverse the epiphyseal plate, but 2 patients (22%) nevertheless showed premature epiphyseal fusion. For 1 patient the epiphyseal fusion could not be determined, while in another patient it was unknown whether or not the osteosynthesis material traversed the epiphyseal plate (table 41).
Premature epiphyseal fusion occurred in 2 (10%) of the 24 patients (55%) who received primary conservative treatment; for 4 patients this was unknown (table 40).
Premature epiphyseal fusion occurred only in patients with a transcervical fracture; in 4 patients (80%) it was associated with avascular necrosis, and in 3 patients (60%) it caused a difference in leg length.

Table 40. Treatment and premature fusion of the epiphysis.

Primary treatment	N	Premature epiphyseal fusion Yes	No	Unknown
Operative	20 (45%)	3 (16%)	16 (84%)	1
Conservative	24 (55%)	2 (10%)	18 (90%)	4
	44	5 (13%)	34 (87%)	5

Table 41. Position of osteosynthesis material and premature fusion of the epiphysis.

Osteosynthesis material	N	Premature epiphyseal fusion Yes	No	Unknown
Transepiphyseal	9 (47%)	1 (11%)	8 (89%)	-
Nonepiphyseal	10 (53%)	2 (22%)	7 (78%)	1
Unknown	1	-	1	-
	20	3 (16%)	16 (84%)	1

IX.5.4 *Non-union*

None of the 58 patients in this follow-up study showed non-union of the fracture. One patient (nr. 011) with a basal (type III) fracture showed delayed union. A subtrochanteric osteotomy was performed, whereupon fracture union did occur.

IX.5.5 *Posttraumatic osteoarthritis of the hip-joint*

Posttraumatic osteoarthritis of the hip-joint developed in 13 of the 56 patients (23%): on the homolateral side in 9 (16%) and on both sides in 4 (7%); in 2 patients this could not be determined. It developed after a proximal femoral fracture in 3 children (18%) and 10 adolescents (26%), i.e. in 5 females (26%) and 8 males (22%). It occurred after a road traffic accident in 5 patients (19%), after a fall from a great height in 5 others (30%) and after a fall on the hip or otherwise in 3 patients (25%). It occurred in 10 patients with a type II (transcervical) fracture (31%), 2 patients with a type III (basal) fracture (15%) and 1 patient with a type IV (pertrochanteric) fracture (9%). At the time of the fracture the epiphyseal

Table 42. Clinical data, treatment and posttraumatic osteoarthritis of the hip-joint.

Clinical data and treatment	N_{56}	Posttraumatic osteoarthritis of the hip-joint None 43 (77%)	Fractured hip 9 (16%)	Both hips 4 (7%)
Age				
child	17 (30%)	14 (82%)	2 (12%)	1 (6%)
adolescent	39 (70%)	29 (74%)	7 (18%)	3 (8%)
Sex				
female	19 (34%)	14 (74%)	4 (21%)	1 (5%)
male	37 (66%)	29 (78%)	5 (14%)	3 (8%)
Cause of accident				
road traffic accident	27 (48%)	22 (81%)	5 (19%)	–
fall from a height	17 (30%)	12 (70%)	3 (18%)	2 (12%)
other type of fall	12 (22%)	9 (75%)	1 (8%)	2 (17%)
Fracture type				
Type I	–	–	–	–
Type II	32 (57%)	22 (69%)	7 (22%)	3 (9%)
Type III	13 (23%)	11 (85%)	2 (15%)	–
Type IV	11 (20%)	10 (91%)	–	1 (9%)
Epiphysis				
open	39 (70%)	31 (79%)	5 (13%)	3 (8%)
closed	12 (21%)	10 (84%)	1 (8%)	1 (8%)
unknown	5 (9%)	2 (40%)	3 (60%)	–
Displacement				
none	10 (18%)	10 (100%)	–	–
present	36 (64%)	28 (78%)	5 (14%)	3 (8%)
unknown	10 (18%)	5 (50%)	4 (40%)	1 (10%)
Delay treatment				
0-24 hrs	36 (64%)	30 (83%)	5 (14%)	1 (3%)
>24 hrs	20 (36%)	13 (65%)	4 (20%)	3 (15%)
Primary treatment				
conservative	30 (54%)	23 (77%)	5 (17%)	2 (6%)
operative	26 (46%)	20 (77%)	4 (15%)	2 (8%)
Treatment				
conservative	26 (46%)	22 (85%)	2 (8%)	2 (8%)
conservative/operative	4 (7%)	1 (25%)	3 (75%)	–
operative	26 (46%)	20 (75%)	4 (15%)	2 (8%)
operative/conservative	–	–	–	–
Delay operation	N_{26}	20 (77%)	4 (15%)	2 (8%)
0-24 hrs	10 (38%)	8 (80%)	2 (20%)	–
>24 hrs	16 (62%)	12 (75%)	2 (12%)	2 (12%)

plate was open in 8 patients (21%) and closed in 2 (16%); in 3 patients (60%) this could not be determined. Displacement was present in 8 patients (22%), while in 5 patients (50%) this could not be determined. Primary treatment was conservative in 7 patients (23%) and operative in 6 (23%). It was commenced immediately in 6 patients (17%), but in 7 patients (35%) it was delayed by more than 24 hours. A delay in operation did not influence the development of posttraumatic osteoarthritis of the hip-joint.
Table 42 presents a survey of the clinical data, methods of treatment and occurrence of posttraumatic osteoarthritis of the hip-joint.

IX.5.6 *Discussion*

At the time of the follow-up the radiographic features of the proximal femur were normal in 34 patients (60%); slight changes in these features were present in 13 patients (23%), and serious changes in 10 (17%); in 1 patient the features could not be assessed. Changes in radiographic features developed less often in children than in adolescents, and as often in females as in males. The difference between children and adolescents is caused by the large number of pertrochanteric fractures in the group of children. The accident cause exerted no influence on the radiographic features of the proximal femur, with the exception of a fall on the hip while walking: this was always followed by a change in radiographic features. In these cases there were no pre-existent changes in the radiographic features of the proximal femur. These changes occurred most often in fractures with epiphyseal fusion and in displaced fractures, and mainly in type II (transcervical) fractures. A delay in treatment of more than 24 hours influenced the radiographic findings, as did the method of treatment. Slight radiographic changes occurred especially after primary operative treatment of the fracture, and in fractures which has been reduced. The type of osteosynthesis material used, and whether or not it traversed the epiphyseal plate, had no influence on the radiographic findings, but the time of operation had. Radiographic changes occurred less often after operations performed within 24 hours than after operations delayed by more than 24 hours (40% and 64%, respectively).
Avascular necrosis was present in 10 patients (17%); it was of Ratliff type I in 8 (14%), of Ratliff type III in 2 (3%) and of Ratliff type II in none of the patients. It occurred more often in children than in adolescents, and in all cases occurred after a transcervical fracture, frequently a fracture of type IV according to Garden or of type II or III according to Pauwels classification. It

occurred more often after primary conservative than after primary operative treatment, and more often in fractures with an open epiphyseal plate and with displacement. The risk of a disturbed vascularization of the proximal femur exists in particular in children with a transcervical fracture, and this risk increases with fracture displacement. Conservatively treated patients with a transcervical fracture also run a risk of secondary disturbances in the vascularization of the proximal fracture, which can give rise to avascular necrosis.

Premature epiphyseal fusion occurred in 5 patients (11%), all with a transcervical fracture, and in 4 patients (80%) was associated with avascular necrosis. A distinct correlation with either primary conservative or primary operative treatment was not demonstrable. Nor was a correlation demonstrable with the passage of osteosynthesis material through the epiphyseal plate.

Non-union of the fracture was not seen in any of the patients.

Posttraumatic osteoarthritis of the hip-joint was present in 13 patients (23%): on the homolateral side in 9 (16%) and on both sides in 4 patients (7%). It occurred especially after a transcervical fracture and displaced fractures, less frequently after a basal fracture. The cause of the accident, epiphyseal fusion or non-fusion, and the method of treatment were of no influence in this respect.

IX.6 Short-term and long-term social consequences

In an interview with the patient and with the parents (if available), an attempt was made to gain insight the short-term and long-term social consequences of proximal femoral fractures. The points noted were:

— The choice of education and occupation.
— Medical examination for military service and subsequent occupation.
— The day-to-day activities.
— Subsequent operations on the proximal femur.

IX.6.1 *The choice of education and occupation*

The duration of morbidity due to a fracture of the proximal femur is long, even in children and adolescents. For many children and adolescents this means an interruption of their school education. The school education was not completed by 2 patients (3%); 8 patients (14%) had to choose a different occupation (i.e. different from their planned occupation).

In none of the patients was a concomitant lesion of influence in the choice of education and occupation.

The completed school education and the demands of the occupation practiced are surveyed in table 43. None of the patients had had to change to a less demanding job later in life, and none had had to discontinue his work owing to complaints concerning the hip.

Table 43. School education and demands of the occupation practiced.

Schooling	N_{58}	Occupation	N_{58}
none	1 (2%)	none	4 (7%)
lo	20 (34%)	scholar	13 (22%)
blo	1 (2%)	housewife	8 (14%)
lbo	20 (34%)	sitting-standing	14 (24%)
mbo	2 (3%)	sitting-standing-walking	8 (14%)
hbo	1 (2%)	standing-walking	9 (16%)
mavo	4 (7%)	very heavy	2 (3%)
havo	7 (13%)		
vwo	2 (3%)		

IX.6.2 *Medical examination for military service and subsequent occupation*

Whether or not medical examinations had to be undergone for military service or a subsequent occupation depends on age, sex and type of occupation chosen.

Of the 33 boys who underwent a medical examination for military service, 21 (64%) were rejected in view of the previous fracture; 6 (18%) were rejected for other reasons, and only 6 (18%) were passed as fit (table 44). Of the 44 patients who underwent a medical examination in relation to their occupation, only 1 (2%) was rejected as unfit because he had been treated in the past for a fracture of the proximal femur (table 44).

Table 44. Medical examination for military service and occupation.

Medical examination for Military Service	N_{33}	Medical examination for occupation	N_{44}
rejected because of fracture	21 (64%)	rejected because of fracture	1 (2%)
rejected for other reason	6 (18%)	rejected for other reason	2 (5%)
accepted	6 (18%)	accepted	41 (93%)
medical examination irrelevant	25	medical examination irrelevant	14

IX.6.3 *Day-to-day activities*

Questions revealed that 5 patients (10%) experienced some degree of restriction in day-to-day activities, mainly manifested in difficulties in donning and shedding socks and shoes due to impaired hip-joint mobility. None of the patients experienced any restriction in personal hygiene.
Of the 46 children and adolescents (76%) actively engaged in sports prior to the accident, 14 (24%) had discontinued these activities.
A survey of impaired hip-joint mobility and disturbed gait has been previously presented. These disturbances handicapped 2 patients (3%) in cycling and driving motor vehicles, but neither employed any adaption for their vehicle. All patients were able to make use of public transport facilities without undue difficulty.

IX.6.4 *Subsequent operations on the proximal femur*

A complication in primary treatment necessitated (re)operation in 14 cases (19%) (table 22). Of the 58 patients studied, 29 (50%) had been treated by internal fixation of the proximal femoral fracture, either as primary treatment or in view of a complication in primary treatment. The osteosynthesis material had been removed in 19 cases (66%). None of the patients in whom the osteosynthesis material was still in situ, experienced difficulties as a result of this situation.
One female patient with a severely deformed proximal femur giving rise to marked osteoarthritis of the hip, had been treated by total hip replacement.

IX.6.5 *Discussion*

Fractures of the proximal femur in childhood or adolescence influenced the choice of education and occupation in 10 cases (17%). Of the boys examined for military service, 21 (64%) were rejected as unfit due to the fracture sustained in the past. Of the patients medically examined before commencing an occupation, only 1 (2%) was rejected as unfit for the above-mentioned reason.
Restrictions in day-to-day activities mainly concern the donning and shedding of socks and shoes (10%), and reduced activities in sports (24%). In only 1 patient did severe impairment of hip-joint mobility, associated with complaints of pain, lead to total hip replacement. None of the remaining patients underwent an operation on the proximal femur or hip-joint at a later age.

IX.7 The results of treatment

Merle d'Aubigné (1949) classified the results of treatment on the basis of the ability to walk, hip mobility and presence of pain in the hip-joint (tables 31, 32 and 33). The maximum score according to Merle d'Aubigné was 18 points. The result was good (18 points) in 38 patients (71%), fair (17 points) in 5 (9%) and poor (less than 17 points) in 11 (20%). In 4 patients the result could not be assessed (table 45).

Table 45. Results of treatment.

Results	Merle d'Aubigné N_{54}	Ratliff N_{56}	Hoekstra N_{54}
Good	38 (71%)	29 (52%)	29 (54%)
Fair	5 (9%)	14 (25%)	11 (20%)
Poor	11 (20%)	13 (23%)	14 (26%)
Unknown	4	2	4

Ratliff (1962) classified the results of treatment of proximal femoral fractures in children and adolescents on the basis of presence of pain in the hip-joint, hip mobility, activity and radiographic findings (table 46). The maximum score according to Ratliff was 12 points. The result was good (12 points) in 29 patients (52%), fair (11 points) in 14 (25%) and poor (less than 11 points) in 13 patients (23%). In 2 patients the result could not be assessed (table 45).

Table 46. The assessment of results of treatment according to Ratliff.

	Good	Fair	Poor
Pain	None or "ignores"	Occasional	Severe
Movement	Full or terminal restriction	Greater than 50%	Less than 50%
Activity	Normal	Normal or avoids games	Restricted
Radiographic indications	Normal or mild deformity of the femoral neck	Severe deformity of the femoral neck. "Mild avascular necrosis"	Severe avascular necrosis. Degenerative arthritis. Arthrodesis

All patients in the follow-up study were asked to give their opinion on the result of treatment achieved. It was described as good by 46 patients (82%), as fair by 8 patients (14%) and as poor by 2 patients (4%); the remaining

Table 47. Clinical data and results of treatment according to Ratliff's criteria.

Clinical data	N_{56}	Results of treatment Good 29 (52%)	 Fair 14 (25%)	 Poor 13 (23%)
Age				
child	17 (30%)	12 (70%)	2 (12%)	3 (18%)
adolescent	39 (70%)	17 (43%)	12 (31%)	10 (26%)
Sex				
female	20 (36%)	9 (45%)	4 (20%)	7 (35%)
male	38 (64%)	20 (55%)	10 (28%)	6 (17%)
Cause of accident				
road traffic accident	27 (48%)	14 (52%)	6 (22%)	7 (26%)
fall from a height	17 (31%)	10 (58%)	4 (24%)	3 (18%)
other type of fall	4 (7%)	-	3 (75%)	1 (25%)
miscellaneous	8 (14%)	5 (63%)	1 (12%)	2 (25%)
Fracture type				
Type I	-	-	-	-
Type II	32 (59%)	12 (35%)	11 (32%)	9 (27%)
Type III	13 (22%)	7 (54%)	3 (23%)	3 (23%)
Type IV	11 (19%)	10 (91%)	-	1 (9%)
Epiphysis				
open	39 (70%)	22 (56%)	9 (23%)	8 (21%)
closed	12 (21%)	6 (50%)	5 (42%)	1 (8%)
unknown	5 (9%)	1 (20%)	-	4 (80%)
Displacement				
none	9 (16%)	6 (67%)	3 (33%)	-
slight	10 (18%)	7 (70%)	1 (10%)	2 (20%)
complete	27 (48)	12 (44%)	10 (37%)	5 (19%)
unknown	10 (18%)	4 (40%)	-	6 (60%)
Fracture type II displacement	N_{32}	12 (35%)	11 (32%)	9 (27%)
Garden I	5 (16%)	3 (60%)	2 (40%)	-
Garden II	5 (16%)	4 (80%)	-	1 (20%)
Garden III	2 (6%)	1 (50%)	1 (50%)	-
Garden IV	16 (50%)	4 (25%)	8 (50%)	4 (25%)
unknown	4 (12%)	-	-	4 (100%)
Fracture type II displacement	N_{32}	12 (35%)	11 (32%)	9 (27%)
Pauwels I	4 (12%)	3 (75%)	1 (25%)	-
Pauwels II	22 (69%)	9 (41%)	9 (41%)	4 (18%)
Pauwels III	2 (6%)	-	1 (50%)	1 (50%)
unknown	4 (12%)	-	-	4 (100%)

Table 48. Treatment and results of treatment according to Ratliff's criteria.

Treatment	N_{56}	Results of treatment Good 29 (52%)	Fair 14 (25%)	Poor 13 (23%)
Delay treatment				
0-24 hrs	37 (66%)	19 (51%)	10 (27%)	8 (22%)
>24 hrs	19 (34%)	10 (53%)	4 (21%)	5 (26%)
Primary treatment				
conservative	29 (52%)	19 (66%)	3 (10%)	7 (24%)
operative	27 (48%)	10 (37%)	11 (41%)	6 (22%)
Treatment				
conservative	26 (46%)	19 (73%)	3 (12%)	4 (15%)
conservative/operative	3 (6%)	–	–	3 (100%)
operative	26 (46%)	10 (39%)	11 (42%)	5 (19%)
operative/conservative	1 (2%)	–	–	1 (100%)
Reduction				
none	20 (36%)	15 (75%)	3 (15%)	2 (10%)
closed	29 (52%)	11 (38%)	10 (34%)	8 (28%)
open	5 (9%)	2 (40%)	1 (20%)	2 (40%)
unknown	2 (3%)	1 (50%)	–	1 (50%)
Reduction achieved				
anatomical	23 (41%)	11 (48%)	7 (30%)	5 (22%)
almost anatomical	19 (34%)	11 (58%)	5 (26%)	3 (16%)
nonanatomical	5 (9%)	3 (60%)	2 (40%)	–
unknown	9 (16%)	4 (44%)	–	5 (56%)
Delay operation	N_{27}	10 (37%)	11 (41%)	6 (22%)
0-24 hrs	10 (37%)	4 (40%)	4 (40%)	2 (20%)
>24 hrs	17 (63%)	6 (35%)	7 (41%)	4 (24%)
Fixation	N_{27}	10 (37%)	11 (41%)	6 (22%)
screws	9 (33%)	5 (56%)	1 (11%)	3 (33%)
Knowles pins	4 (15%)	–	3 (75%)	1 (25%)
nail	12 (44%)	4 (33%)	7 (58%)	1 (8%)
miscellaneous	2 (7%)	1 (50%)	–	1 (50%)
Fixation	N_{27}	10 (37%)	11 (41%)	6 (22%)
transepiphyseal	17 (63%)	5 (29%)	8 (47%)	4 (24%)
nonepiphyseal	9 (33%)	4 (44%)	3 (33%)	2 (22%)
unknown	1 (4%)	1 (100%)	–	–
Period				
1909-1960	23 (41%)	10 (43%)	6 (26%)	7 (30%)
1960-1981	33 (59%)	19 (58%)	8 (24%)	6 (18%)

2 patients could give no opinion due to concomitant lesions. If the patient's subjective opinion was accounted for in assessment of the result according to Ratliff, then the maximum score was 16 points. In this way the result of

treatment was found to be good (16 points) in 29 patients (54%), fair (15 points) in 11 (20%) and poor (less than 15 points) in 14 (26%). In the remaining 4 patients the result could not be assessed (table 45).
The patient's opinion exerted no significant influence on the result of treatment. The difference in result between the Merle d'Aubigné score and the Ratliff score lies in the assessment of the radiographic indications. It is on the basis of this radiographic assessment that the result of treatment is accurately classified as good, fair or poor.
On the basis of the result of treatment as assessed according to the criteria of Ratliff (table 46), the clinical data and treatment results of 56 of the 58 Groningen patients were evaluated (tables 47 and 48).
The result of treatment of fractures of the proximal femur was better in children than in adolescents. This is explained by the larger number of pertrochanteric fractures in the children's group. The accident cause did not determine the result, but the type of fracture did. Specifically in proximal femoral fractures with an open epiphyseal plate, in type II (transcervical) fractures and in displaced fractures, the result of treatment was less satisfactory. Of the transcervical (type II) fractures, particularly those of Garden type IV and of Pauwels type II or III showed poor results (table 47).
The result was found not to be evidently related to a delay in primary conservative or operative treatment. The result after primary conservative treatment was better than that after primary operative treatment, even though a poor result was observed as often after primary conservative as after primary operative treatment. In this context it is to be noted that primary conservative treatment was received by most patients with type III (basal) fractures and with type IV (pertrochanteric) fractures.
Primary operative treatment of fractures of the proximal femur was often followed by slight changes in the radiographic features of the proximal femur, and this also influenced the result of treatment.
The result of treatment was slightly better after screw fixation than after Knowles pin fixation and nail fixation. The result of treatment was worse after transepiphyseal than after non-transepiphyseal fixation. The result was better in fractures which did not require reduction than in those that did. The reduction achieved did not determine the result.
The prognosis of proximal femoral fractures in children and adolescents has improved in the course of the past 20 years. This can be attributed mainly a decrease in the complications of primary treatment since transcervical fractures are no longer treated conservatively but receive operative treatment.

SUMMARY AND CONCLUSIONS

Fractures of the proximal femur in children and adolescents are rare. An explorative retrospective study was undertaken in an effort to gain more insight into the aetiology and the clinical features of these fractures in children and adolescents, in relation to the method of treatment used and the short-term or long-term results achieved. For this purpose a follow-up study was made of 58 of the 74 children and adolescents treated for proximal femoral fractures at the Department of Surgery of the Groningen University Hospital during the period 1909-1981. This thesis describes the results of this explorative retrospective study.

Chapter I presents an introduction and defines the aims of this investigation.

Chapter II describes the anatomy of the hip and the development of the arterial vascularization of the proximal femur. The proximal femur is vascularized by three different systems which, as the proximal femur grows, differ in the contribution they make to the circulation. Between the 4th month and the 7th year of life the vessels in the ligamentum capitis femoris take no part in the vascularization of the femoral head. After the 4th year of life the contribution made by the metaphyseal vessels decreases, the femoral head receiving blood only via the lateral epiphyseal vessels and the ligamentum capitis femoris not yet contributing to the vascularization of the femoral head. After the 7th year of life the vessels in the ligamentum capitis femoris resume a role in the vascularization of the femoral head, while the blood supply via the metaphyseal vessels still remains limited. The latter increases towards the end of adolescence. Finally, epiphyseal fusion occurs and the vascularization of the proximal femur is provided by vessels from the ligamentum capitis femoris, the epiphyseal and the metaphyseal vessels.

Chapter III presents a review of the fractures of the proximal femur, which can be classified into 4 fracture types: traumatic separation of the upper femoral epiphysis (type I), transcervical fractures (type II), basal or cervico-trochanteric fractures (type III) and pertrochanteric fractures (type IV).

Type I and type IV are both extremely rare. Fractures of the proximal femur involve great forces acting on the proximal femur directly or indirectly. Due to the anatomical situation in the region of the proximal femur, displaced fractures produce characteristic clinical features: the fractured leg is shortened and lies in external rotation and adduction.

Chapter IV presents a review of complications of fracture healing. Six such complications are distinguished: avascular necrosis, delayed union and non-union, posttraumatic coxa vara, premature epiphyseal fusion, difference in leg length, and arthritis. Avascular necrosis or posttraumatic ischaemic necrosis is caused by disturbances in the circulation of the proximal femur. The risk that such disturbances occur is determined by the type of fracture, presence or absence of displacement, the patient's age and the method of treatment. Three types of avascular necrosis are distinguished: avascular necrosis of the femoral head and neck (type I), avascular necrosis of the epiphysis (type II) and avascular necrosis of the femoral neck (type III). Delayed union is present when union does not occur within 3 months; the term non-union applies when union fails to occur within 6 months. Non-union is not an independent complication in fracture healing but is in part due to other complications such as avascular necrosis and posttraumatic coxa vara. The coxa vara after proximal femoral fractures is a result of a complication of fracture healing. The primary cause of this abnormality lies in avascular necrosis with or without damage to the epiphyseal plate. Coxa vara is reportedly somewhat more common after conservative than after operative fracture treatment. It need not be detrimental to the result of treatment, and can be regarded as the least serious complication. Premature epiphyseal fusion can be caused by damage to the epiphyseal plate or a disturbance in its vascularization, and is likely to give rise to disturbances in the growth of the proximal femur manifested in changes in the position of the proximal femur and/or a difference in leg length. A difference in leg length can result from premature epiphyseal fusion, avascular necrosis of the proximal femur, posttraumatic coxa vara or valga, or non-union. Septic arthritis is a rare complication after a proximal femoral fracture; it is usually iatrogenic, but may also develop as a result of bacteraemia. It results in chondrolysis, i.e. necrosis of the articular cartillage.

Chapter V describes the patients studied and the method of investigation used.

Chapter VI presents a survey of the clinical data. The relative incidence of proximal femoral fractures in children and adolescents versus that in adults was 1:34 in this study. The incidence in boys was twice as high as that in girls. The cause of the fracture was severe violence, a road traffic accident or a fall from a great height, in 75% of the cases. Type II (transcervical) fractures were most frequently involved (58%), followed by type III (basal) fractures (23%), type IV (pertrochanteric) fractures (16%) and traumatic separation of the upper femoral epiphysis (type I) (3%). There was a slight predilection for the left side, and 80% of the fractures were displaced. Displacement was slightly less often seen in type IV (pertrochanteric) fractures, and more often in children than in adolescents. An associated injury was involved in 28% of the cases, and mainly involved the pelvis, the extremities and the head.

Chapter VII presents a historical review of developments in the treatment of proximal femoral fractures in children and adolescents. This is followed by a review of indications for primary conservative or operative fracture treatment and of the various methods of treatment used. Treatment of complications of fracture healing is also reviewed. Type IV (pertrochanteric) and some type III (basal) fractures can be treated conservatively with traction in abduction. Type I (traumatic separation of the upper femoral epiphysis), type II (transcervical) and displaced type III (basal) fractures require operative treatment with internal fixation. Internal fixation is preferably effected with cancellous bone screws or Knowles pins. Children and adolescents with proximal femoral fractures require a prolonged follow-up with a view to possible short-term or long-term complications of fracture healing. Treatment of these complications of fracture healing is determined largely by individual findings and depends on the type of complication and the associated short-term or long-terms symptoms.

Chapter VIII describes the methodology of the follow-up.

Chapter IX discusses the results of the follow-up. Impaired hip-joint mobility was present in 10 patients (18%). A disturbed gait was observed in 12 patients (22%), while 8 patients (14%) complained of pain in the hip. More specifically, functional results were less good after type II (transcervical) fractures and after primary conservative treatment.
The fractured leg was shortened in 7 patients (17%) and lengthened in 4 (9%). Shortening was seen only after transcervical fractures, and lengthening after transcervical and pertrochanteric fractures. Posttraumatic coxa vara developed in 3 patients (5%) and posttraumatic coxa valga in 5 (9%), usually after transcervical fractures. Both leg shortening and coxa vara or

valga developed more frequently after primary conservative than after primary operative treatment.

Changes in the radiographic features of the proximal femur occurred in 23 patients (40%); they were slight in 12 (23%) and serious in 10 patients (17%). The slight changes in radiographic features were seen mostly in undisplaced fractures with epiphyseal fusion, in transcervical and, to a lesser extent, in basal fractures. Serious radiographic changes were observed in displaced transcervical fractures.

Avascular necrosis developed in 10 patients (17%); it was of Ratliff type I in 8 (14%) and of Ratliff type III in 2 patients (3%), while none of the patients developed Ratliff type II avascular necrosis. Avascular necrosis was observed only after transcervical fractures, and preferably if they were displaced and showed no epiphyseal fusion (type IV according to Garden or Pauwels type II or type III). Avascular necrosis was found in 29% of the patients with a transcervical fracture. It was more frequently seen after primary conservative (36%) than after primary operative treatment (25%).

Premature epiphyseal fusion was often associated with avascular necrosis, and occurred only after transcervical fractures.

None of the patient showed non-union of the fracture.

Posttraumatic osteoarthritis of the hip-joint developed in 13 patients (23%); it was confined to the homolateral hip in 9 (16%) and involved both hips in 4 patients (7%).

The proximal femoral fracture influenced the choice of education and occupation in 10 cases (17%). Restrictions in day-to-day activities concerned mainly difficulties in donning and sheeding socks and shoes (10%) and reduced activities in sports (24%). Impaired hip-joint mobility and complaints about pain in the hip finally necessitated total hip replacement in only 1 patient.

Conclusions

The findings obtained in this study and the data from the literature would seem to warrant the following conclusions and recommendations for treatment.

Proximal femoral fractures are far less common in children and adolescents than in adults. This study revealed that only 3% of all proximal femoral fractures seen at the Groningen University Hospital occurred in children and adolescents. These fractures are more common in adolescents than in children and are about 1¾ times as frequent in boys as in girls. In most cases the cause is a serious accident. A fall from a great height used to be the principal cause in the past, but road traffic accidents rank first today. An concomitant lesion, mostly of the pelvis, the extremities and the head, was present in at least a quarter of all patients.

Four fracture types can be distinguished: traumatic separation of the upper femoral epiphysis (type I), transcervical fractures (type II), basal or cervico-trochanteric fractures (type III) and pertrochanteric fractures (type IV). Transcervical fractures are the most common fractures of the proximal femur, followed by basal fractures and pertrochanteric fractures; traumatic separation of the upper femoral epiphysis is the least common. Pertrochanteric fractures occur more often in children than in adolescents. A correlation between the type of accident and type of fracture was not demonstrable.

Complications of fracture healing occur especially after traumatic separation of the upper femoral epiphysis and after transcervical fractures, and less often after basal and pertrochanteric fractures. These complications of fracture healing are determined not only by the fracture type but also by the patient's age and the presence or absence of fracture displacement. The principal causes of complications of fracture healing are avascular necrosis of the femoral head and changes in the position of the proximal femur.

These complications of fracture healing give rise to a difference in leg length, posttraumatic osteoarthritis of the hip-joint, disturbed gait and/or walking distance, impaired hip-joint mobility and pain in the hip. Moreover, these fractures in children and adolescents can influence the choice of education and subsequent occupation.

Traumatic separation of the upper femoral epiphysis (type I), transcervical (type II) and displaced basal (type III) fractures require primary operative treatment with internal fixation. Undisplaced basal (type III) and pertrochanteric (type IV) femoral fractures can be treated conservatively with traction in extension-abduction. In the patients with severe multiple injuries, primary operative treatment may be preferred in the two last-mentioned cases.

Operative treatment should be given as soon after the accident as possible, and should include decompression of the hip-joint to relieve a possible intracapsular haematoma via capsulotomy or puncture. After open or closed anatomical reduction, internal fixation of the fracture is effected with cancellous bone screws or Knowles pins. If immediate surgery is impossible, then it is sufficient to puncture the hip-joint and apply traction in extension-abduction. Traction should amount to one-fifth of the body weight. The operation can then be performed in a second session.

As assessed in accordance with the criteria formulated by Ratliff, the result of treatment of proximal femoral fractures in children and adolescent is poor in about a quarter of the patients. The result is determined on the one hand by the type of fracture and the patient's age, and on the other hand by the method of treatment and the complications which attend it. The result of treatment is determined mainly by the presence or absence of avascular necrosis of the femoral head. The risk that avascular necrosis develops is determined by the type of fracture, the degree of displacement, the patient's age, epiphyseal fusion or non-fusion, and the method of treatment.

Complications of fracture healing leading to disturbances in the growth and development of the proximal femur and hip-joint are most likely to occur after displaced type II (transcervical) fractures when the vascularization of the proximal femur has not yet fully developed. Eventually, these complications will give rise to functional impairment of the involved hip-joint.

SAMENVATTING EN CONCLUSIES

Fracturen van het proximale femur bij kinderen en adolescenten zijn zeldzaam. Om meer inzicht te verkrijgen in de etiologie en de klinische gegevens van deze fracturen bij kinderen en adolescenten en de relatie met de uitgevoerde behandeling en de genezingsresultaten op korte- of lange termijn werd een exploratief, retrospectief onderzoek verricht. Hiertoe werden 58 van de 74 kinderen of adolescenten met een fractuur van het proximale femur, die gedurende de periode 1909-1981 in de Heelkundige Kliniek van het Academisch Ziekenhuis te Groningen werden behandeld, na-onderzocht. Dit proefschrift beschrijft de resultaten van dit exploratief, retrospectief onderzoek.

In hoofdstuk I wordt na een inleiding de doelstellingen van dit onderzoek omschreven.

In hoofdstuk II wordt de anatomie van de heup en de ontwikkeling van de arteriële vascularisatie van het proximale femur beschreven. Het proximale femur wordt door 3 verschillende systemen van bloed voorzien, die gedurende de groei van het proximale femur verschillend bijdragen in de circulatie van het proximale femur. Vanaf de 4e levensmaand tot het 7e jaar nemen de vaten in het ligamentum capitis femoris geen deel aan de bloedvoorziening van het caput femoris. Na het 4e levensjaar neemt het aandeel van de metaphysaire vaten af en wordt het caput femoris alleen nog van bloed voorzien via de laterale epiphysaire vaten. Het ligamentum capitis femoris neemt nog geen deel aan de bloedvoorziening van het caput femoris. Vanaf het 7e levensjaar gaan de vaten in het ligamentum capitis femoris weer een rol spelen in de voeding van het caput femoris, terwijl de bloedvoorziening via de metaphysaire vaten nog gering blijft. Deze neemt toe tegen het eind van de adolescentie. Tenslotte treedt sluiting van de epiphysairschijf op en verzorgen de vaten uit het ligamentum capitis femoris, de epiphysaire- en metaphysaire vaten de vascularisatie van het proximale femur.

In hoofdstuk III wordt een overzicht gegeven van de fracturen van het proximale femur. Er kan een onderscheid gemaakt worden in 4 typen fracturen. De traumatische epiphysiolysis van het caput femoris (type I), de mediale collum femoris fractuur (type II), de laterale collum femoris fractuur (type III) en de pertrochantere femurfractuur (type IV). Zowel de traumatische epiphysiolysis van het caput femoris als de pertrochantere femurfractuur zijn zeer zeldzame fracturen. Voor het ontstaan van fracturen van het proximale femur zijn grote krachten nodig die direct of indirect op het proximale femur inwerken. Door de anatomische verhoudingen in het gebied van het proximale femur ontstaat bij gedisloceerde fracturen een kenmerkend klinisch beeld, het gefractureerde been is verkort, ligt in exorotatie en adductie.

In hoofdstuk IV wordt een overzicht gegeven van de stoornissen in de fractuurgenezing. Een zestal stoornissen in de fractuurgenezing kunnen worden onderscheiden: avasculaire necrose, vertraagde consolidatie en pseudo-arthrose, coxa vara posttraumatica, voortijdig sluiten van de epiphysairschijf, beenlengte-verschil en arthritis. Avasculaire necrose of post-traumatische ischaemische necrose van het proximale femor wordt veroorzaakt door stoornissen in de circulatie van het proximale femur. De kans op het optreden van dergelijke stoornissen in de bloedvoorziening van het proximale femur wordt bepaald door het type fractuur, het al of niet gedisloceerd zijn, de leeftijd van de patient en de behandeling. Er kunnen 3 typen avasculaire necrosen worden onderscheiden: avasculaire necrose van het caput- en collum femoris (type I), avasculaire necrose van de epiphyse (type II) en avasculaire necrose van het collum femoris (type III). Wanneer na 3 maanden nog geen consolidatie van een fractuur is opgetreden, is er sprake van een vertraagde consolidatie en na een ½ jaar van een pseudo-arthrose. De pseudo-arthrose is een niet op zich zelf staande stoornis in de fractuurgenezing maar wordt ten dele veroorzaakt door andere stoornissen in de fractuurgenezing, zoals avasculaire necrose en coxa vara posttraumatica. De coxa vara posttraumatica na een proximale femurfractuur is het gevolg van een stoornis in de fractuurgenezing. De primaire oorzaak van het ontstaan van deze afwijking is gelegen in de avasculaire necrose met al of niet beschadiging van de epiphysairschijf. De coxa vara zou iets vaker na conservatief, dan na operatief behandelde fracturen van het proximale femur voorkomen. De coxa vara behoeft geen afbreuk te doen aan het uiteindelijke behandelingsresultaat en kan als de minst ernstige complicatie beschouwd worden. Voortijdig sluiten van de epiphysairschijf kan veroorzaakt worden door beschadiging van de epiphysairschijf of door een stoornis in de vascularisatie van de epiphysairschijf en zal aanleiding geven tot het ontstaan van groeistoornissen van het proximale femur, die zich kunnen uiten in standsafwijkingen van het proximale femur en/of beenlengte-verschil. Verschil in beenlengte kan het gevolg zijn van een voortijdig sluiten van de epiphysairschijf, het optreden van een avasculaire necrose van het proximale femur, een coxa vara of valga posttraumatica of een pseudo-arthrose. Een septische arthritis is een zeldzaam optredende complicatie na een fractuur van het proximale femur en meestal van iatrogene aard, doch kan ook in aansluiting aan een bacteriëmie ontstaan. De septische arthritis heeft een chondrolysis, necrose van gewrichtskraakbeen tot gevolg.

In hoofdstuk V wordt het patientenmateriaal en de methode van het onderzoek beschreven.

In hoofdstuk VI wordt een overzicht gegeven van de klinische gegevens. De frequentie van voorkomen van proximale femurfracturen bij kinderen en adolescenten ten opzichte van volwassenen bedroeg in het onderzoek 1 : 34. De proximale femurfractuur kwam twee keer vaker voor bij jongens dan bij meisjes. De oorzaken van ontstaan van proximale femurfracturen was in 75% een ernstig inwerkend geweld, een verkeersongeval of een val van grote hoogte. De mediale collum femoris fractuur, type II was de meest voorkomende fractuur (58%), gevolgd door de laterale collum femoris fractuur, type III (23%), de pertrochantere femurfractuur, type IV (16%) en de traumatische epiphysiolysis van het caput femoris, type I (3%). Proximale femurfracturen kwamen iets vaker links dan rechts voor en waren in 80% van de gevallen gedisloceerd. De pertrochantere femurfracturen (type IV) waren iets minder vaak gedisloceerd dan de andere fracturen en kwam vaker voor bij kinderen dan bij adolescenten. Bij 28% van de patienten was er sprake van een begeleidend letsel en dit betrof voornamelijk het bekken, de extremiteiten en het hoofd.

In hoofdstuk VII wordt na een historisch overzicht over de ontwikkeling van de behandeling van proximale femurfracturen bij kinderen en adolescenten een overzicht gegeven van de indicatie tot conservatieve en/of operatieve behandeling en de diverse methoden van behandeling. Daarnaast wordt een overzicht gegeven van de behandeling van stoornissen in de fractuurgenezing. De pertrochantere femurfractuur (type IV) en eventueel de niet-gedisloceerde laterale collum femoris fractuur (type III) kunnen conservatief behandeld worden met tractie in abductie. De traumatische epiphysiolysis van het caput femoris (type I), de mediale collum femoris fractuur (type II) en de gedislocerde laterale collum femoris fractuur (type III), dienen operatief behandeld te worden met behulp van een interne fixatie. Hierbij gaat de voorkeur uit naar spongiosa schroeven of „Knowles pins". Kinderen en adolescenten met een proximale femurfractuur dienen gedurende een lange tijd onder controle te blijven in verband met eventuele stoornissen in de fractuurgenezing op korte of lange termijn. De behandeling van een stoornis in de fractuurgenezing is sterk individueel bepaald en afhankelijk van de stoornis en de daarmee gepaard gaande klachten op korte of lange termijn.

In hoofdstuk VIII wordt de methode van het na-onderzoek beschreven.

In hoofdstuk IX worden de resultaten uit het na-onderzoek beschreven. Een stoornis in de bewegingsmogelijkheid van het heupgewricht was bij 10 patienten (18%) aanwezig. Een stoornis in het looppatroon was aanwezig bij 12 patienten (22%) en bij 8 patienten (14%) bestonden pijnklachten in het heupgewricht. Het functionele resultaat was met name slechter na een mediale collum femoris fractuur (type II) en na een conservatieve behandeling.
Een beenlengte-verkorting trad op bij 7 patienten (17%) en een toename van de beenlengte bij 4 patienten (9%). Verkorting trad alleen op na mediale collum femoris fracturen en een toename van de beenlengte na mediale collum femoris fracturen en pertrochantere femurfracturen. Een coxa vara posttraumatica trad op bij 3 patienten (5%) en een coxa valga posttraumatica bij 5 patienten (9%) en ontstond voornamelijk na mediale collum femoris fracturen. Zowel een beenlengte-verkorting als een standsafwijking van het proximale femur ontstond vaker na een conservatieve behandeling dan na een operatieve behandeling.
Een verandering van het röntgenologische aspect van het proximale femur trad op bij 23 patienten (40%), bij 13 (23%) bestonden geringe veranderingen van het röntgenologische aspect en ernstige veranderingen bij 10 (17%). De geringe veranderingen van het röntgenologische aspect traden vooral op bij de niet-gedisloceerde fracturen met gesloten epiphysairlijnen en voornamelijk mediale collum femoris fracturen en in mindere mate na laterale collum femoris fracturen. De ernstige afwijkingen van het röntgenologisch aspect traden op bij de gedislocეerde mediale collum femoris fracturen.
Avasculaire necrose trad op bij 10 patienten (17%); 8 keer een avasculaire necrose, type I volgens Ratliff (14%), 2 keer een avasculaire necrose, type III volgens Ratliff (3%) en bij geen der patienten een avasculaire necrose type

II volgens Ratliff. De avasculaire necrose trad slechts op na een mediale collum femoris fractuur, bij voorkeur gedisloceerde mediale collum femoris fracturen met open epiphysairlijnen, type IV volgens Garden of type II en type III volgens Pauwels. Bij 29% van de patienten met een mediale collum femoris fractuur werd een avasculaire necrose gezien. Avasculaire necrose trad vaker op na een conservatieve (36%) dan na operatieve behandeling (25%).
Een voortijdige sluiting van de epiphysairschijf ging vaak gepaard met een avasculaire necrose en trad alleen op na mediale collum femoris fracturen.
Een pseudo-arthrose was bij geen der patienten aanwezig.
Een posttraumatische arthrosis van het heupgewricht ontstond bij 13 patienten (23%); bij 9 (16%) alleen aan de gefractureerde zijde, bij 4 patienten (7%) in beide heupgewrichten.
Bij 10 patienten (17%) was de proximale femurfractuur van invloed op de keuze van onderwijs en beroep. Een beperking in de dagelijkse activiteiten kwam vooral tot uiting in de beperking van het aan en uittrekken van de schoenen en de sokken (10%) en een verminderde sportbeoefening (24%). Slechts 1 patient kreeg wegens bewegingsbeperking en pijnklachten in het heupgewricht, te zamen met pijnklachten een totaal arthroplastiek van het heupgewricht.

Conclusie

Op basis van de bevindingen van dit onderzoek en de gegevens uit de literatuur, kunnen de volgende conclusies worden getrokken en aanbevelingen met betrekking tot de behandeling worden gedaan.

Bij kinderen en adolescenten komt de proximale femurfractuur veel minder vaak voor dan bij volwassenen. In dit onderzoek kwamen slechts 3% van alle proximale femurfracturen voor bij kinderen en adolescenten. De fractuur komt vaker voor bij adolescenten dan bij kinderen en 1¾ keer vaker bij jongens dan bij meisjes. De oorzaak is in de meeste gevallen een ernstig ongeval. In het verleden was de val van grote hoogte de voornaamste oorzaak, heden ten dage is deze plaats ingenomen door het verkeersongeval. Bij ruim een kwart van alle patienten is er sprake van een begeleidend letsel van voornamelijk de extremiteiten, het bekken en het hoofd.
Er kan een onderscheid gemaakt worden in 4 typen fracturen: traumatische epiphysiolysis van het caput femoris (type I), mediale collum femoris fractuur (type II), laterale collum femoris fractuur (type III) en pertrochantere femurfractuur (type IV). De mediale collum femoris fractuur is de meest

voorkomende fractuur van het proximale femur gevolgd door de laterale collum femoris fractuur, de pertrochantere femurfractuur en de traumatische epiphysiolysis van het caput femoris. Bij kinderen treden frequenter pertrochantere femurfracturen op, dan bij adolescenten. Een relatie tussen type ongeval een type fractuur was niet aantoonbaar.
Stoornissen in de fractuurgenezing treden vooral op bij traumatische epiphysiolysis van het caput femoris en mediale collum femoris fracturen en in mindere mate bij laterale collum femoris fracturen en pertrochantere femurfracturen. Deze stoornissen in de fractuurgenezing worden niet alleen bepaald door type fractuur, maar ook door leeftijd van de patient en eventuele aanwezige dislocatie van de fractuur. Avasculaire necrose van het caput-collum femoris en standsafwijkingen van het proximale femur zijn de voornaamste stoornissen in de fractuurgenezing.
Deze stoornissen in de fractuurgenezing veroorzaken beenlengte-verschil, post-traumatische arthrosis van het heupgewricht, stoornis in het looppatroon en/of de loopafstand, stoornis in de beweeglijkheid van het heupgewricht en pijnklachten in het heupgewricht. Daarnaaast is deze fractuur bij kinderen en adolescenten van invloed op de keuze van onderwijs en/of beroep.
De traumatische epiphysiolysis van het caput femoris (type I), de mediale collum femoris fractuur (type II) en de gedisloceerde laterale collum femoris fractuur (type III) dienen operatief behandeld te worden met behulp van interne fixatie. De niet-gedisloceerde laterale collum femoris fractuur (type III) en de pertrochantere femurfractuur (type IV) kunnen conservatief behandeld worden met tractie in extensie-abductie. Bij de meervoudig ernstig gewonde patient kan in deze laatste twee gevallen de voorkeur uitgaan naar een operatieve behandeling.
De operatieve behandeling dient zo spoedig mogelijk na het ongeval plaats te vinden, waarbij een decompressie van het heupgewricht ter ontlasting van een eventueel aanwezig intracapsulair haematoom via een punctie of capsulotomie wordt verricht. De interne fixatie, van de anatomisch bloedig of onbloedig gereponeerde fractuur, geschiedt met spongiosaschroeven of „Knowles pins". Wanneer niet direct een operatieve behandeling kan plaats vinden, dan wordt volstaan met het puncteren van het heupgewricht en het aanleggen van een tractie in extensie-abductie. De tractie moet 1/5 van het lichaamsgewicht bedragen. In tweede instantie kan dan alsnog operatie plaats vinden.

Het eindresultaat van de behandeling van proximale femurfracturen bij kinderen en adolescenten is volgens de criteria van Ratliff bij circa een kwart van de patienten slecht. Dit eindresultaat wordt enerzijds bepaald door type fractuur en leeftijd van de patient en anderzijds door de behandeling en de optredende stoornissen in de behandeling. Het wel of niet optreden van een avasculaire necrose van het caput-collum femoris bepaalt voornamelijk het uiteindelijke resultaat van de behandeling. Type fractuur, mate van dislocatie, leeftijd van de patient, het al of niet open zijn van de epiphysairlijnen en de wijze van behandeling bepalen de kans op het optreden van een avasculaire necrose.
Stoornissen in de fractuurgenezing, de groei en ontwikkeling van het proximale femur en heupgewricht zullen vooral optreden bij gedisloceerde mediale collum femoris fracturen (type II), waarbij de vascularisatie van het proximale femur nog niet volledig ontwikkeld is. Zij zullen tenslotte aanleiding geven tot een verminderde gebruiksmogelijkheid van het getroffen heupgewricht.

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